Central Valley Project Improvement Act

Draft

Programmatic

Environmental

Impact

Statement

US Department of the Interior

Bureau of Reclamation

Sacramento, California

LIST OF TECHNICAL APPENDICES
(SEPTEMBER 1997)

VOLUME ONE	Development of the No-Action Alternative Summary of Pre-CVPIA Conditions Evaluation of Preliminary Alternatives Public Involvement
VOLUME TWO	Surface Water Supplies and Facilities Operations Soils and Geology Groundwater CVP Power Resources
VOLUME THREE	Fisheries
VOLUME FOUR	Vegetation and Wildlife Recreation Fish, Wildlife and Recreation Economics
VOLUME FIVE	Agricultural Economics and Land Use Water Transfer Opportunities Municipal and Industrial Land Use and Demographics Municipal Water Costs Regional Economics Social Analysis
VOLUME SIX	Visual Resources Air Quality Cultural Resources Delta as a Source of Drinking Water
VOLUME SEVEN	PROSIM M/M SANJASM M/M CVGSM M/M
VOLUME EIGHT	**CVPM M/M** **CVPTM M/M** **Municipal Water Costs M/M** **IMPLAN M/M**
VOLUME NINE	Fish Habitat Water Quality M/M Vegetation and Wildlife M/M Recreation M/M Fish Wildlife and Recreation Economics M/M

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CENTRAL VALLEY PROJECT IMPROVEMENT ACT PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT

DRAFT METHODOLOGY/MODELING TECHNICAL APPENDIX

CVPM M/M

September 1997

TABLE OF CONTENTS

C-083775

C-083775

LIST OF FIGURES

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

ac	acre
af	acre-feet
AFRP	Anadromous Fish Restoration Program
ARP	acreage reduction percent
AUM	animal unit per month
AW	applied water
CE	University of California Cooperative Extension Service
CES	Constant Elasticity of Substitution
COE	U.S. Army Corps of Engineers
CPS	consumers' and producers' surplus
CVGSM	Central Valley Ground-Surface Water Simulation Model
CVP	Central Valley Project
CVPM	Central Valley Production Model
CVPTM	Central Valley Production and Transfer Model
CVPIA	Central Valley Project Improvement Act
CVP-OCAP	Central Valley Project Operations Criteria and Plan
DAU	detailed analysis unit
Delta	Sacramento-San Joaquin Delta
DWR	California Department of Water Resources
ET	evapotranspiration
ETAW	evapotranspiration of applied water
KCWA	Kern County Water Agency
kWh	kilowatt-hour
NEPA	National Environmental Policy Act
O&M	operations and maintenance
PEIS	Programmatic Environmental Impact Statement
PMP	Positive Mathematical Programming
PROSIM	Project Simulation Model
Reclamation	U.S. Bureau of Reclamation
SANJASM	San Joaquin Area Simulation Model
Service	U.S. Fish and Wildlife Service
SWP	State Water Project
WWD	Westlands Water District

CHAPTER I

INTRODUCTION

Chapter I

INTRODUCTION

The Central Valley Production Model (CVPM) is a regional model of irrigated agricultural production and economics that simulates the decisions of agricultural producers (farmers) in the Central Valley of California. The model assumes that farmers maximize profit subject to resource, technical, and market constraints. Farmers sell and buy in competitive markets, and no one farmer can affect or control the price of any commodity. To obtain a market solution, the model's objective function maximizes the sum of producers' surplus (net income) and consumers' surplus (net value of the agricultural products to consumers) subject to the following relationships and restrictions:

(1) Linear, increasing marginal cost functions estimated using the technique of positive mathematical programming. These functions incorporate acreage response elasticities that relate changes in crop acreage to changes in expected returns and other information;

(2) Commodity demand functions that relate market price to the total quantity produced;

(3) Irrigation technology tradeoff functions that describe the tradeoff between applied water and irrigation technology; and

(4) A variety of constraints involving land and water availability and other legal, physical, and economic limitations.

The model selects those crops, water supplies, and irrigation technology that maximize profit subject to these equations and constraints. Profit is revenue minus costs. From 1 above, cost per acre increases as production increases. Revenue is irrigated acreage, times crop yield per acre, times crop price. From 2 above, crop price and revenue per acre decline as production increases. Component 3 affects costs and water use through the selection of the least-cost irrigation technology. Component 4 is used to analyze the impacts of Central Valley Project Improvement Act (CVPIA) provisions that change water availability and cost. Component 4 also ensures that the model incorporates real-world hydrologic, economic, technical, and institutional constraints.

The model includes 22 crop production regions in the Central Valley and 26 categories of crops. A map of the regions appears as Figure I-1. Descriptions of each of the regions and crop types are provided in Tables I-1 and I-2, respectively.

This technical appendix describes the version of the CVPM used in the CVPIA Programmatic Environmental Impact Statement (PEIS). The model was revised during the study, so model inputs and structure described here may differ from earlier versions described in other documents or used in other studies.

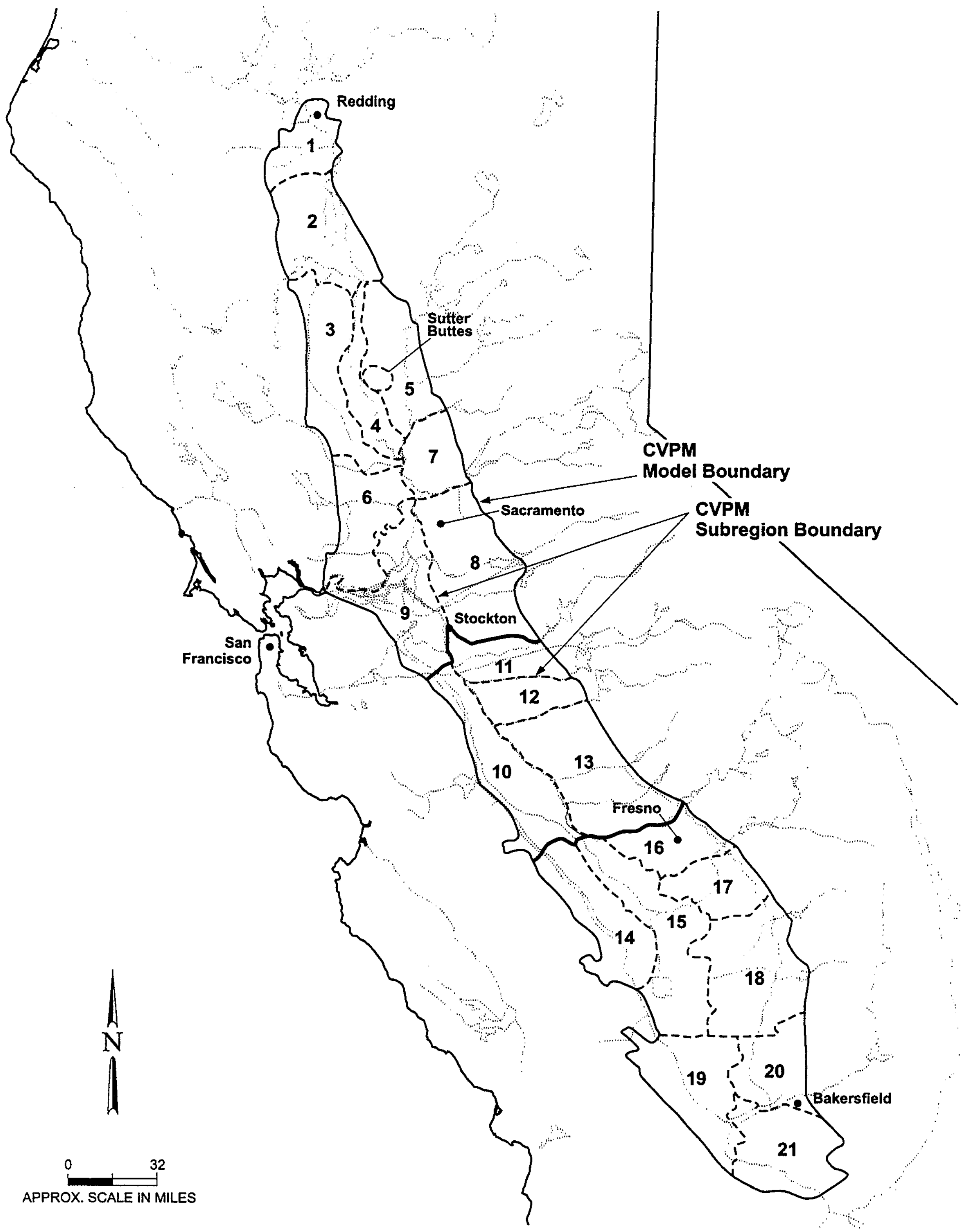

FIGURE I-1

DEFINITION OF CVPM SUBREGIONS

TABLE I-1

CVPM REGIONS AND DESCRIPTIONS

CVPM Region	Description of Major Water Users
1	CVP Users: Anderson Cottonwood, Clear Creek, Bella Vista, Sacramento River miscellaneous users.
2	CVP Users: Corning Canal, Kirkwood, Tehama, Sacramento River miscellaneous users.
3	CVP Users: Glenn Colusa ID, Provident, Princeton-Codora, Maxwell, and Colusa Basin Drain MWC.
3b	Tehama Colusa Canal Service Area. CVP Users: Orland-Artois WD, most of County of Colusa, Davis, Dunnigan, Glide, Kanawha, La Grande, Westside WD.
4	CVP Users: Princeton-Codora-Glenn, Colusa Irrigation Co., Meridian Farm WC, Pelger Mutual WC, Recl. Dist. 1004, Recl. Dist. 108, Roberts Ditch, Sartain M.D., Sutter MWC, Swinford Tract IC, Tisdale Irrigation, Sac River miscellaneous users.
5	Most Feather River Region riparian and appropriative users.
7	Sacramento Co. north of American River. CVP Users: Natomas Central MWC, Sac River miscellaneous users, Pleasant Grove-Verona, San Juan Suburban.
6	Yolo, Solano Counties. CVP Users: Conaway Ranch, Sac River Miscellaneous users.
9	Delta Regions. CVP Users: Banta Carbona, West Side, Plainview.
8	Sacramento Co. south of American River, San Joaquin Co.
10	Delta Mendota Canal. CVP Users: Panoche, Pacheco, Del Puerto, Hospital, Sunflower, West Stanislaus, Mustang, Orestimba, Patterson, Foothill, San Luis WD, Broadview, Eagle Field, Mercy Springs, Pool Exchange Contractors, Schedule II water rights, more.
11	Stanislaus River water rights: Modesto ID, Oakdale ID, South San Joaquin ID.
12	Turlock ID.
13	Merced ID. CVP Users: Madera, Chowchilla, Gravely Ford.
14	CVP Users: Westlands WD.
15	Tulare Lake Bed. CVP Users: Fresno Slough, James, Tranquillity, Traction Ranch, Laguna, Real. Dist. 1606.
16	Eastern Fresno Co. CVP Users: Friant-Kern Canal. Fresno ID, Garfield, International.
17	CVP Users: Friant-Kern Canal. Hills Valley, Tri-Valley Orange Cove.
18	CVP Users: Friant-Kern Canal, County of Fresno, Lower Tule River ID, Pixley ID, portion of Rag Gulch, Ducor, County of Tulare, most of Delano Earlimart, Exeter, Ivanhoe, Lewis Cr., Lindmore, Lindsay-Strathmore, Porterville, Sausalito, Stone Corral, Tea Pot Dome, Terra Bella, Tulare.
19	Kern Co. SWP Service Area.
20	CVP Users: Friant-Kern Canal. Shafter-Wasco, S. San Joaquin.
21	CVP Users: Cross Valley Canal, Friant-Kern Canal. Arvin Edison.

TABLE I-2

CVPM CROP GROUPINGS

Category	Proxy Crop (1)	Other Crops (2)	Unit of Measure
Wheat	Wheat		Tons
Miscellaneous grain	Barley	Oats, sorghum	Tons
Rice	Rice		Tons
Cotton	Upland cotton	Pima cotton	480-lb bales
Sugar beets	Sugarbeets		Tons
Corn	Field corn	Miscellaneous field crops	Tons
Miscellaneous hay	Grain hay	Sudan grass, other silage	Tons
Dry beans	Dry beans	Lima beans	Tons
Oil seed	Safflower	Sunflower	Tons
Alfalfa seed	Alfalfa seed	Wild rice, miscellaneous seed crops	Tons
Alfalfa	Alfalfa hay		Tons
Pasture	Irrigated pasture		Animal Unit Months
Processing tomatoes	Processing tomatoes		Tons
Fresh tomatoes	Fresh tomatoes		Tons
Melons	Canteloupe	Honeydew, watermelon	Tons
Onions	Dry onions	Dry and fresh onions, garlic	Tons
Potatoes	White potatoes		Tons
Miscellaneous vegetables	Peppers	Carrots, cauliflower, lettuce, peas, spinach, broccoli, asparagus, sweet potatoes, other truck vegetables	Tons
Almonds	Almonds	Pistachios	Tons
Walnuts	English walnuts		Tons
Prunes	Prunes	Plums and apricots	Tons
Peaches	Peaches	Nectarines, pears, cherries, apples, miscellaneous deciduous fruit	Tons
Citrus	Oranges	Lemons, grapefruit, miscellaneous subtropical fruit	Tons
Olives	Olives	Figs, kiwis, avocados, pomegranates	Tons
Raisin grapes	Raisins	Table grapes	Tons
Wine grapes	Wine grapes		Tons

NOTES:
(1) Production costs, yields, and prices for this crop used in the CVPM.
(2) Acreage data for these crops summed with the proxy crop.

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PURPOSE

The CVPM is used to assess the impacts on irrigated agriculture of implementing provisions of the CVPIA. The model is linked to hydrologic impact analysis in order to show how water supply changes affect agricultural production and, in turn, how economic responses to these changes affect land use and the demand for and use of water supplies. A modified version of the model is used to assess opportunities and potential benefits and impacts of interregional water transfers.

The following direct effects of the CVPIA are assessed using CVPM:

- Reduction in water supplies caused by reallocation of water to environmental purposes
- Reduction in water supplies caused by purchases for fish and wildlife restoration
- Implementation of a land retirement program
- Restoration charges and tiered (block rate) water pricing
- Water transfer provisions

DEVELOPMENT HISTORY

The CVPM was developed by the California Department of Water Resources (DWR) and has been revised for this analysis in cooperation with DWR. An important reason for selecting CVPM as a modeling tool was to develop and refine a model that would be consistent with DWR's future planning and policy analyses. The model is based on an optimization technique known as positive mathematical programming. A description of the technique appears in Howitt (1995).

Several models of California agriculture based on the technique have contributed to the theory and application of the CVPM. These precursors have been used to estimate field crop losses caused by air pollution (Howitt and Goodman, 1989) and drought (Howitt, 1994), demand functions for water (Howitt, 1983), interregional water transfers (Vaux and Howitt, 1984), impacts of changes in water supplies (Farnam, 1994), and impacts of drainage control policies (Hatchett et al., 1991; Dinar et al., 1991). The technique has been applied to economic problems in many other settings.

DOCUMENTATION

CVPM has undergone a series of revisions within DWR since its initial development, and no formal documentation of the model has been made available to the public. Farnam (1994) provides the first comprehensive description of CVPM prior to its use in the CVPIA assessment. Because CVPM has been significantly revised and updated since 1994, this Technical Appendix is the only currently applicable description of the model.

REVIEW OF CVPM

As part of the analytical methods development for the CVPIA analysis, CVPM has undergone a series of workshops and a formal peer review. In addition to continual review and improvement by the analytical team, CVPM has been through several more formal review processes:

- As part of the Analytical Tools review and selection, CVPM was evaluated and compared to other potential approaches for estimating agricultural impacts. It was chosen as the preferred tool because of its geographic coverage, its flexible structure, and its ongoing development and use by DWR. Data needs and structural improvements were noted at the time of its selection and have been substantially met.

- During the fall of 1994 a series of internal review meetings was held with Reclamation and the Service to discuss the agricultural impact modeling and to identify categories of impacts that CVPM could and could not estimate.

- In December of 1994, an independent peer review panel assembled to review the capability of CVPM for providing analysis for the CVPIA impacts. The panel was asked to review data, model structure, and results of sensitivity analysis. The consensus of the panel was that CVPM has the most comprehensive database and the most flexibility of the available tools, and is appropriate for the analysis. Several reviewers suggested future refinements. Others pointed out that some kinds of impacts are not well evaluated with regional models and need to be addressed in other ways (these included impacts of risk and uncertainty, and associated financial impacts). A list of panel members and summary notes from the review are available on request.

- In January of 1995, an Analytical Tools Workshop was held in Sacramento to allow members of agencies, interested groups, and the general public to hear a description of the CVPM and how it would be used in the CVPIA analysis. Oral and written comments were recorded.

QUALIFICATIONS ON THE USE OF CVPM

CVPM is an optimization model that assumes agricultural decision-makers maximize long-run or short-run profit subject to a number of resource limitations. As a result, it derives the best possible response (measured in profit) to changes in conditions. Actual decision-makers, especially in the short run, do not have access to perfect information on water supplies, prices, and markets, and do not have immediate access to financing in order to make the best possible adjustments to changes in conditions. Actual responses will be less than optimal, so an optimization model tends to underestimate changes that reduce profit (net revenue) and overestimate changes that increase profit.

CVPM incorporates much flexibility in the categories of adjustment allowed as conditions change; changing crops, fallowing land, pumping groundwater, and adjusting irrigation efficiency are potential adjustments individually or in combination. Depending on how these interact, an underestimation of impacts on profit may result in either an under- or overestimating of changes in these individual categories. Other, more simple impact estimation methods that do not incorporate as much flexibility may err in the other direction, by overestimating reductions in profit.

The degree to which a decision-maker's response to a change in condition is optimal (as defined by CVPM) depends on information available, physical and financial flexibility, and the amount of time available for learning about and adjusting to the new circumstances. The primary impact analysis in the PEIS uses the year 2020 as the basis for comparing conditions with and without implementing CVPIA. It is assumed, therefore, that 20-25 years after implementation is sufficient to learn and adjust to the changes. Impacts immediately following implementation are almost certain to be more pronounced. Short-run adjustments to dry or wet conditions are also assessed using a more restricted form of CVPM that does not allow the flexibility of the long-run model.

Another qualification to the use of CVPM or any model used to estimate conditions in 2020 is the potential for structural and technological changes. Important changes that could occur between now and 2020 include international trade rules, consumer demand shifts, and agricultural and irrigation technology improvements. Trying to predict these changes is highly speculative and beyond the scope of CVPM and the analysis used in the PEIS.

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CHAPTER II

DESCRIPTION OF CVPM

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Chapter II

DESCRIPTION OF CVPM

POSITIVE MATHEMATICAL PROGRAMMING AND MODEL CALIBRATION

Traditional optimization models such as linear programming rely on data based on observed average conditions (e.g., average production costs, yields, and prices), which are expressed as fixed coefficients. As a result, these models tend to select crops with the highest average returns until resources (land, water, capital) are exhausted. The predicted crop mix is therefore less diverse than we observe in reality. The most widespread reason for diversity of crop mix is the underlying diversity in growing conditions and market conditions. Simply put, any crop-producing region includes a broad range of production conditions. All farms and plots of land do not produce under the same, average set of conditions; therefore, the marginal cost and revenue curves do not coincide with average cost and revenue curves.

Economic theory suggests that economic decisions are based on marginal (incremental) conditions, and that these differ from the average conditions. Positive Mathematical Programming (PMP) is a technique developed to incorporate both marginal and average conditions into an optimization model. In the conventional case of diminishing economic returns, productivity declines as output increases. Therefore, the marginal cost of producing another unit of crop increases as production increases and the marginal cost exceeds the average cost. The PMP technique uses this idea to reproduce the variety of crops observed in the data.

Several possible or combined reasons for crop diversity are: diverse growing conditions that cause variation in production costs or yield; crop diversity to manage and reduce risk; and constraints in marketing or processing capacity. The CVPM assumes that the diversity of crop mix is caused by factors that can be represented as increasing marginal production cost for each crop at a regional level. For example, CVPM costs per acre increase for cotton farmers as they expand production onto more acreage. The PMP approach used in CVPM uses empirical information on acreage responses and shadow prices—implicit prices of resources—based on standard linear programming techniques and a calibration period data set. The acreage response coefficients and shadow prices are used to calculate parameters of a quadratic cost function that is consistent with economic theory. The calibrated model will then predict exactly the original calibration data set, and can be used to predict impacts of specified policy changes such as changes in water supplies. Attachment A describes the approach in more detail.

Calibration refers to the calculation of some model parameters in such a way that the model will predict a given set of target data. The CVPM is calibrated against two categories of information: irrigated acreage by crop and by region and applied water (or irrigation efficiency) by crop and by region. Each category represents the target parameter (e.g., acres by crop by region) and has one or more calibration parameters calculated or adjusted in order for the model to match the target. The historical data set covers the 1985 through 1992 period, and the model can be calibrated to any subset of these years. For the PEIS, the years 1987 through 1990 are used. This period was chosen for several reasons. First, although this period falls within the seven year drought of 1985 to 1992, the storage and operations of the CVP avoided large delivery shortages until 1991 and 1992. The average deliveries during the calibration period were reasonably representative of contract volumes. Second, this period provided a basis for the model confirmation analysis described later. Third, at the time the CVPIA analysis was being designed, these years provided the most recent, available data on cropping patterns, prices, and deficiency payments without using the severe drought years of 1991 and 1992.

For calibrating to crop acreage, the calibration parameters are the coefficients of the quadratic total cost (linear marginal cost) function, as derived in Attachment A. The derivation of these parameters guarantees that the model will duplicate the calibration period crop acreage if no other data are changed. In addition, the calibration parameters for crop acres are calculated in such a way that the calculated net revenue in the calibration period equals the observed net revenue for that period. In other words, the acreage calibration parameters change the marginal costs but not the average or total costs in the calibration period. The other piece of information used to calculate the calibration parameters is the acreage response elasticity, described below.

ACREAGE RESPONSE ELASTICITIES AND PMP COEFFICIENTS

Acreage response elasticities show how farmers change their planted acreage in response to changes in expected price, revenue, or profit. Acreage response elasticity is defined here as the percent change in acreage of a crop due to a percent change in expected revenue per acre. The CVPM incorporates acreage response elasticities directly within the linear marginal cost functions as part of the PMP calculations. The shadow prices calculated as part of the PMP procedure indicate the deviation between marginal and average cost, but they do not provide information on the slope of the marginal cost function. This is the role of the acreage response elasticity.

Attachment A describes how the acreage response elasticities and the crop shadow prices are used to create the marginal cost functions in the CVPM. The elasticities used are provided in Table II-1. The estimation of these elasticities is described in Attachment B.

COMMODITY DEMAND FUNCTIONS AND PRICE FLEXIBILITIES

Commodity demand functions show the price buyers are willing to pay for agricultural goods as a function of the total quantity put up for sale. The CVPM uses linear commodity demand functions derived from secondary information in the form of price flexibilities. Price flexibility is defined as the percent change in market price caused by a percent change in quantity produced and sold.

Price flexibilities must be appropriate to the region being analyzed, in this case the Central Valley. The CVPM is set up to read in California-wide flexibilities and then adjust them for Central Valley-only flexibilities. The Central Valley price flexibility is equal to the statewide flexibility times the proportion of California production of the commodity grown in the Central Valley. These proportions were obtained from DWR (1993). California flexibilities and the share of California production from the Central Valley as used in the CVPM are provided in Table II-1.

TABLE II-1

CALIFORNIA PRICE FLEXIBILITY, SHARE OF CALIFORNIA PRODUCTION FROM THE CENTRAL VALLEY, AND LONG- AND SHORT-RUN ACREAGE RESPONSE ELASTICITIES

Crop	Price Flexibility(1)	CA Share from Central Valley	Acreage Response Elasticity		
			Data Source (2)	Long Run	Short Run
Wheat	-0.00	0.50	1	0.38	0.30
Miscellaneous grain	-0.00	0.50	1	0.39	0.16
Rice	-0.05	1.00	1	0.30	0.18
Cotton	-0.05	0.97	2	0.64	0.36
Sugar beets	-0.10	0.80	2	0.19	0.11
Corn	0.00	0.50	1	0.45	0.21
Miscellaneous hay	-0.20	0.63	1	1.89	0.63
Dry bean	-0.20	0.85	1	0.17	0.13
Oil seed	-0.20	0.90	1, 2	0.34	0.34
Alfalfa seed	-0.20	0.63	2	0.34	0.34
Alfalfa	-0.50	0.63	1	0.51	0.24
Pasture	-0.50	0.66	2	0.30	0.15
Process tomatoes	-0.25	1.00	1	0.28	0.15
Fresh tomatoes	-0.20	0.50	1	0.31	0.16
Melons	-0.20	0.70	1	0.05	0.05
Onions	-0.20	0.58	1	0.19	0.11
Potatoes	-0.50	0.75	2	0.19	0.11
Misc. vegetables	-0.20	0.35	2	0.19	0.11
Almonds	-0.50	1.00	2	0.04	0.03
Walnuts	-0.25	0.93	2	0.01	0.01
Prunes	-0.80	0.98	2	0.33	0.14
Peaches	-0.50	0.97	1	0.30	0.23
Citrus	-0.80	0.70	2	0.04	0.03
Olives	-0.50	0.95	2	0.01	0.01
Raisin grapes	-0.80	1.00	2	0.09	0.08
Wine grapes	-0.80	0.55	2	0.03	0.02

NOTES:
1. Price flexibility is the percent change in price divided by the percent change in quantity produced.
2. Data source categories are: 1=Estimated with Central Valley time-series, cross-sectional data; or 2=Literature values or values for similar commodities used.

Existing estimates of California price flexibilities from the agricultural economics literature were used. Commodities that could not be found in existing studies were approximated using values for similar kinds of commodities. Details are provided in Attachment B. 1985 to 1992 price and production data are combined with the price flexibility to construct a linear demand function. As CVPM commodity production changes because of changes in water supplies, the model predicts changes in market price.

In general, price changes are not an important impact of changes in water supplies because most of the commodities most likely to be idled by water shortages are produced for national or international markets associated with small California price flexibilities. One exception to this generalization is alfalfa. Local production declines can cause significant local price increases because of inelastic demands for feed, especially for horses and dairy cattle, and large transportation costs.

IRRIGATION TECHNOLOGY ADJUSTMENTS

The cost functions derived with the PMP technique govern changes in acreage of different crops as conditions change. Those functions do not affect the mix of inputs used to grow a crop. Inputs used to produce an acre of an irrigated crop include labor, water, irrigation system investments, other capital investments, fertilizer, and chemicals. Although any of these inputs could be adjusted in response to a change in water policy, water use and irrigation system investments are of particular interest for this effort. Especially, the CVPIA will affect water availability and price, and irrigation system investments can be used to reduce water use and cost per acre.

The CVPM includes tradeoff functions, or isoquants, between water use and irrigation system cost. For purposes of the CVPM irrigation tradeoff functions, water use is defined as applied water (AW) divided by evapotranspiration of applied water (ETAW). This ratio is referred to as Relative AW, and is the inverse of the most commonly used measure of field-level irrigation efficiency. Because ETAW varies regionally, using the ratio of AW to ETAW in the estimation allows the parameters of the tradeoff functions to be more site independent.

In order to estimate the tradeoff functions, data on irrigation system cost and performance were updated from an earlier study prepared for Reclamation (CH2M HILL, 1991). The updated study (CH2M HILL, 1994) is available upon request. Attachment B provides a description with examples of how the irrigation cost and performance information was used to estimate the tradeoff functions.

In the CVPM, both applied water and irrigation system cost are decision (endogenous) variables. Profit maximizing (or cost minimizing) conditions require that the ratio of water price to irrigation technology price be equal to the ratio of the marginal products of water andirrigation technology. Given an estimate of the isoquant, an observed Relative AW also defines the irrigation system cost.

There are several ways of calibrating the model to observed applied water. The current version of CVPM uses the estimated isoquant parameters and assumes that the observed water use-irrigation technology mix is cost minimizing, and the model calculates the implied irrigation technology price needed for this to be true. The rationale for this calibration approach is explained in more detail in Attachment A.

FEDERAL FARM PROGRAMS

The CVPM incorporates U.S. Department of Agriculture commodity programs, as authorized in 1990 farm legislation, by adding effective deficiency payments to the market prices of eligible commodities in the long-run analysis. Effective deficiency payments are calculated as the difference between the 1990 Farm Bill target price and the national average market price, times the percentage of participating acres in a region; they are then reduced 15 percent for "flex" acreage. Deficiency payment rates used in the analysis are provided in Table II-2. Deficiency payments and participation rates for program crops were obtained from the Agricultural Stabilization and Conservation Service (1994).

TABLE II-2

EFFECTIVE DEFICIENCY PAYMENT ($ PER TON UNLESS NOTED)

Commodity		1985	1986	1987	1988	1989	1990	1991	1992
Corn	Sacramento Valley	$11	$25	$24	$8	$13	$12	$8	$15
	San Joaquin Valley	4	9	8	3	5	4	3	5
Misc. Grains	Sacramento Valley	10	19	15	0	0	4	11	10
	San Joaquin Valley	7	12	9	0	0	3	7	6
Wheat	Sacramento Valley	25	46	41	16	8	31	27	17
	San Joaquin Valley	16	29	25	10	5	20	18	11
Cotton	San Joaquin, $/bale	70	75	50	59	38	43	27	53
Rice	Sacramento Valley	78	94	96	86	71	84	52	72
	San Joaquin Valley	78	94	96	86	71	84	52	72

NOTE:
Adjustments for acreage reduction percent (ARP), flex acreage, and participation rates are included.
SOURCE:
State ASCS Office

The Federal Agriculture Improvement and Reform Act became law in April of 1996. The law replaces deficiency payments with market transition payments which are independent of the crop grown. Acreage reduction set-asides are no longer required. These farm program provisions will be in place for seven years, after which the farm program is either renewed or modified, or it reverts to the previous structure. This major change occurred after much of the analysis for this document was complete, and is not incorporated. However, transition payments are about the same amount per acre as the deficiency payments were in the early 1990s, and they are paid during temporarily but not permanently idled land. The CVPM does not currently incorporate the extent of crop-switching now allowed under the 1996 Farm Bill.

SHORT-RUN VERSUS LONG-RUN ANALYSIS

The CVPM is designed to analyze both short-run and long-run responses to changes in water resource conditions. The purpose of the long-run analysis is to estimate economic conditions on average after farmers have made permanent adjustments to changes in hydrologic and economic conditions. The purpose of the short-run analysis is to estimate acreage, crop mix, and water use during a drought, given farmers' best possible responses to the temporary situation.

The two analyses have several important differences involving farmer behavior and the extent to which certain technologies, crops, and costs can be affected in the short run.

- *Variable and fixed costs* can be avoided in the long-run, but only variable costs can be avoided in the short run. Therefore, only variable costs affect decisions in the short run. Fixed costs are subtracted from net returns after the CVPM has decided the best short run response. Both variable and fixed costs affect decisions in the long run because all factors of production can be adjusted.

- The model differentiates *short- and long-run acreage response elasticities.* Short-term elasticities represent the willingness of growers to change acreage of a crop on a year-to-year basis. Long-run elasticities represent more permanent or long-run changes in crop mix.

- Under the 1990 Farm Bill, program participants could reduce their planted base acreage to zero or 50 percent of base, yet still receive 92 percent of deficiency payments. Because 92 percent of payments were received whether or not the crop was grown, they did not affect short-run decisions. The farmer had to grow the crop in the long run to maintain eligibility for the payments, but could idle land temporarily and still receive the payment. *Deficiency payments are included in long-run decisions but not in short-run decisions.* The short-run analysis can account for the value of deficiency payments by adding them to net returns once the CVPM has determined the best short-run response.

- The long-run analysis includes *limitations on perennial crop acreage* determined by running the model with dry-year hydrology to ensure that perennial acreage cannot exceed that which can be supported during drought conditions.

- Investment in irrigation technology is determined by its long-run average profitability. The model holds *irrigation technology constant in the short run.*

- *The water use required for non-bearing perennial acreage is included in the long-run analysis* to account for the average replacement rate of these crops. Production costs, yields, and water use all represent the average over the production cycle. Alfalfa and pasture are on a 4- or 5-year cycle; trees and vines are on a 20- to 40-year cycle (see Table 1 in Attachment B).

OTHER RESOURCE CONSTRAINTS

The model includes several other constraints to account for limited resources.

The CVPM constrains water supplies and allows economics to determine the farmer's best use of them. The model can include as many distinct water sources and costs as are appropriate for a production region. The current model identifies CVP water service contract supply, CVP water rights and exchange supply, State Water Project (SWP) supply, local surface supply, and groundwater as potential sources available in each region.

CVPM can also impose an upper limit on irrigable land. Currently this limit is set at 120 percent of the irrigated acreage during full water supply conditions. This assumption accounts for the maximum irrigable acreage given current facilities, and for purposes of the CVPIA analysis prevents land from becoming a limiting resource.

CVPM DATA HANDLING AND SOURCES FOR CALIBRATION RUN

WATER SUPPLIES

Central Valley Project (CVP). U.S. Bureau of Reclamation (Reclamation) operations data provided the total amounts of CVP water delivered by region. Contract deliveries were obtained from Reclamation (1993, 1994). The difference between total and contract deliveries indicates delivery of base supply of Sacramento River contracts and San Joaquin River exchange contracts.

State Water Project (SWP). SWP deliveries for both water contracts and Feather River water rights were obtained from DWR Bulletin 132 (DWR, various years). Kern County Water Agency (KCWA) annual water supply reports (KCWA, various years) provided more detailed information on SWP deliveries by district.

Local Surface. The Central Valley Ground-Surface Water Model (CVGSM) is used as the primary source of local surface water supply. Additional information from individual districts is used, as available, to supplement the CVGSM estimates. KCWA annual water supply reports provide detailed estimates for Kern County.

Groundwater. The CVGSM is used as the primary source of groundwater pumping estimates. Additional information obtained from individual districts is used, as available, to supplement the CVGSM estimates. KCWA annual water supply reports provide estimates for Kern County, and Westlands Water District (WWD) has made estimates of pumping within its boundaries. All of these estimates are imprecise, and the CVPM calibration procedure uses groundwater pumping as one of the adjustment parameters to achieve balance between water supply and demand.

A summary of surface water supplies used in the calibration run is provided in Table II-3.

TABLE II-3

1987-1990 AVERAGE SURFACE WATER SUPPLIES BY REGION (1,000 ACRE-FEET)

Region	CVP Contract Water	CVP Water Rights and Exchange	State Water Project	Local Surface Water	Total
1	36.1	128.5	0.0	0.0	165
2	42.6	6.0	0.0	87.5	136
3	117.2	792.3	0.0	11.8	921
3B	222.3	0.0	0.0	0.0	222
4	176.8	600.8	0.0	0.0	778
5	13.7	3.6	821.8	256.3	1,095
6	0.8	68.3	0.0	259.5	329
7	21.6	125.5	0.0	201.5	349
8	0.0	0.0	0.0	84.8	85
9	46.3	0.0	0.0	1076.7	1,123
10	450.9	537.3	0.0	173.0	1,161
11	0.0	0.0	0.0	620.3	620
12	0.0	0.0	0.0	408.3	408
13	182.7	57.5	0.0	332.3	572
14	1137.2	0.0	36.6	0.0	1,174
15	56.7	10.0	192.3	325.0	584
16	16.2	0.0	0.0	344.0	360
17	40.8	0.0	0.0	150.8	192
18	383.8	0.0	0.0	137.0	521
19	0.0	0.0	603.2	7.3	610
20	182.5	0.0	45.8	85.8	314
21	87.2	0.0	289.8	37.5	414
Total	3215.2	2329.9	1989.5	4599.0	12133.5

CROP ACREAGE AND CROP MIX

Three primary sources of crop acreage data are available: district-level reports, County Agricultural Commissioner Reports, and DWR land use estimates. Because of the need for a consistent and annual data set that covers all irrigated lands in the Central Valley, the CVPM uses County Agricultural Commissioner crop reports of harvested acreage as the primary data source (County Agricultural Commissioners, 1984 to 1993). County-level electronic data were obtained. Crop acreage was apportioned to CVPM regions using DWR's 1990 land use estimates, which are available by detailed analysis unit (DAU). Additional information obtained from individual districts was used, as available, to adjust these estimates. KCWA annual water supply reports provided crop acreage for Kern County, and WWD provided data for CVPM Region 14 (WWD, various years).

The county crop data include dryland acreage of wheat, miscellaneous grains, miscellaneous hay, and oilseeds. The proportion of this acreage that was not irrigated was estimated based on U.S. agricultural census data (U.S. Department of Commerce, Bureau of the Census, 1987). Adjusting for dryland production gives an estimate of lands that are harvested **and** irrigated. CVPM accounts for all irrigated land, even if it is not harvested (non-harvested lands include non-bearing orchards and vines, cover crops, and crop failures). A second adjustment occurs within the model so that water use depends on irrigated acreage whereas production depends on harvested acreage. The ratio of harvested **and** irrigated to all irrigated is based on a crop and regional comparison of DWR's 1990 irrigated acreage estimates with the dryland-adjusted 1990 CAC estimates.

Table II-4 displays the average calibration period crop acreage by subregion. These data represent lands harvested **and** irrigated. For analysis of 2020 conditions, crops supplies and demands are scaled to match DWR's projected 2020 acreage. This procedure is described in Attachment A.

CROP WATER USE AND ON-FARM IRRIGATION EFFICIENCY

DWR has made estimates by DAU of AW and the crop use of AW (ETAW) for 14 crop categories. CVPM uses these estimates in all but a few cases. A few of the estimates implied an unrealistically high irrigation efficiency, and were adjusted slightly. Crop water use estimates appear in Tables II-5 and II-6.

CROP PRICES AND YIELDS

County Agricultural Commissioner reports provided estimates of prices and yields. The data sometimes showed large, and probably unrealistic, variations in prices or yields between some adjacent counties, possibly because of small samples. Therefore, counties were grouped into five regions from north to south. Yield data were adjusted for the presence of some dryland harvested acreage. In addition, normalized prices and yields (as defined and used in Reclamation crop production budgets) are also calculated from the CAC data and are available in the data set for CVPM. Tables II-7 and II-8 provide crop price and yield data.

WATER COSTS

Water prices in CVPM have two components, a project charge and a district charge. The project charge is the price per acre-foot paid by the district (or contractor) to either the CVP or the SWP. This unit cost is analogous to a wholesale cost, and is zero for water rights supplies. These data were obtained from Reclamation (1993, 1994) and DWR (various years), respectively.

In addition, surface water has a district charge associated with the cost of delivering the water from the source to the farms. The district charge is the amount that local districts charge to recover their costs, and this charge applies to local, SWP, or CVP water.

The district charge is divided into a water charge, or markup, (in dollars per acre-foot) and a land assessment (in dollars per acre), sometimes called a standby charge. Districts with more than one source of water may charge everyone the same markup and assessment or may vary the charge to reflect internal delivery cost differences. CVPM is defined by region, so district charges are averaged over a region and do not vary by source. The cost per acre-foot of water charged to growers is the sum of the wholesale cost and the markup. Standby charges do not vary based on water used, but are included in the overall cost and net revenue calculations. District charges and

TABLE II-4

1987- 1990 AVERAGE ACRES BY REGION AND CROP
(Thousand Acres)

Region	Irrigated Pasture	Alfalfa	Sugar Beets	Other Field Crops	Rice	Truck Crops	Tomato	Deciduous Orchard	Small Grains	Grapes	Cotton	Subtropical Orchard	Total
1	24.5	1.1		0.2				4.2	1.2				31.2
2	32.3	8.3	3.3	13.3	2.2	0.3		62.0	16.5			7.3	145.5
3	7.7	17.9	7.9	19.4	112.1	13.2	17.0	11.6	34.0				240.8
3B	5.3	9.7	4.5	16.4	7.6	0.3	4.0	17.6	9.4			1.0	75.7
4	1.5	7.0	10.3	52.8	76.2	10.1	23.4	22.1	35.6				239.0
5	36.8	4.0	2.1	18.0	146.3	4.4	1.0	101.1	17.8			4.6	336.2
6	11.9	27.5	19.9	64.0	10.2	4.3	41.6	24.0	54.3	0.8			258.5
7	37.4	2.6	4.1	4.2	47.7	0.3	1.2	7.9	11.9	0.1			117.4
8	45.2	15.4	14.3	47.6	5.7	8.9	12.6	34.1	30.9	44.8			259.4
9	22.4	50.3	30.0	119.0	1.0	29.3	34.3	15.1	84.6	5.0			391.0
10	25.5	53.5	26.2	61.9	7.5	61.8	33.4	32.7	38.6	0.6	99.3	2.9	443.8
11	57.2	9.6	0.3	22.8	5.1	3.5	0.6	71.6	10.5	10.8			192.1
12	26.3	26.9	0.1	47.0		2.3		81.0	30.6	14.7	2.4	0.2	231.6
13	72.9	55.1	8.8	74.1	6.2	9.2	6.8	105.9	55.9	90.8	67.7	15.1	568.3
14	0.8	10.3	8.3	30.7		74.4	75.3	14.4	37.4	5.8	259.9	1.3	518.5
15	23.3	115.4	6.7	84.2	0.2	10.3	0.6	29.1	93.7	48.0	280.3	0.8	692.6
16	21.9	7.8		13.2		10.2		19.5	8.9	70.3	12.3	10.4	174.5
17	14.0	8.2	0.1	7.7		6.6	0.6	55.3	7.8	106.9	11.1	30.2	248.5
18	10.7	76.6	3.9	68.7		6.0	0.0	53.4	72.4	47.0	167.0	82.2	588.1
19	2.7	30.8	4.4	12.1		12.5	0.5	42.2	19.9	9.7	114.6	3.5	252.9
20	1.0	16.5	1.0	3.9		15.4	0.2	47.7	8.3	37.7	37.3	25.4	194.4
21	3.3	36.7	6.6	14.8	0.4	72.5	2.6	19.7	25.0	35.0	136.4	15.3	368.3
Total	484.6	591.2	162.7	795.9	428.3	355.9	255.7	872.2	705.2	528.1	1188.4	200.2	6568.4

SOURCE:
County Agricultural Commissioners.

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TABLE II-5

APPLIED WATER PER ACRE BY REGION AND CROP
(Acre-Foot per Acre)

Region	Irrigated Pasture	Alfalfa	Sugar Beets	Other Field Crops	Rice	Truck Crops	Tomato	Deciduous Orchard	Small Grains	Grapes	Cotton	Subtropical Orchard
1	5.06	4.04		2.53				3.73	0.91			
2	4.93	3.94	3.35	2.35	6.40	1.87		3.37	0.89			2.60
3	4.26	3.85	2.99	2.17	6.20	1.74	2.90	3.40	0.85			
3B	4.89	3.91	3.32	2.41	6.20	1.86	3.03	2.99	0.88			2.54
4	4.95	3.95	3.36	2.25	6.43	1.88	3.07	3.34	0.89			
5	4.78	3.83	3.26	2.26	6.22	1.81	2.97	3.39	0.86			2.48
6	5.04	4.03	3.42	2.48	6.56	1.91	3.12	3.53	0.91	2.62		
7	5.13	4.10	3.49	2.44	6.67	1.95	3.18	4.22	0.92	2.67		
8	5.26	4.49	4.16	2.55	7.05	1.79	3.16	3.22	1.02	2.97		
9	5.03	4.40	3.56	2.41	7.24	2.62	3.05	3.65	1.05	2.95		
10	5.00	4.60	3.30	2.83	6.70	1.80	3.30	3.28	1.40	2.80	3.30	2.50
11	4.16	4.21	3.11	2.71	6.72	1.81	2.71	3.05	0.75	2.46		
12	4.71	4.76	3.42	2.70		2.03		3.12	1.07	2.67	3.40	2.62
13	4.55	4.54	3.25	2.95	6.94	2.10	3.00	3.13	1.12	2.88	3.29	2.54
14	4.16	3.96	3.27	2.20		2.13	3.07	3.29	1.29	2.67	3.02	2.67
15	4.69	4.25	3.54	2.55	6.87	2.26	3.41	3.52	1.54	2.97	3.33	2.97
16	4.62	4.62		2.90		2.26		2.90	1.08	2.65	3.05	2.36
17	4.70	4.70	3.20	2.83		2.00	3.10	3.18	1.20	2.60	3.15	2.35
18	4.59	4.59	3.37	3.02		1.84	3.26	3.53	1.43	2.86	3.16	2.55
19	4.61	4.40	3.64	2.25		1.95	3.38	3.43	1.67	2.97	3.38	2.82
20	4.79	4.79	3.67	2.93		1.94	3.37	3.23	1.48	2.96	3.37	2.75
21	4.83	4.73	3.65	2.89	6.93	1.94	3.38	3.39	1.62	3.00	3.41	2.82

SOURCE:
DWR.

TABLE II-6

ET OF APPLIED WATER BY REGION AND CROP
(Acre-Foot per Acre)

Region	Irrigated Pasture	Alfalfa	Sugar Beets	Other Field Crops	Rice	Truck Crops	Tomato	Deciduous Orchard	Small Grains	Grapes	Cotton	Subtropical Orchard
1	3.33	2.92		1.83				2.59	0.68			
2	3.63	3.10	2.61	1.90	3.75	1.36		2.65	0.71			2.10
3	3.22	2.89	2.35	1.69	3.65	1.25	2.06	2.50	0.67			
3B	3.43	3.00	2.46	1.86	3.65	1.29	2.14	2.28	0.70			1.98
4	3.37	2.95	2.42	1.72	3.58	1.27	2.11	2.43	0.69			
5	3.28	2.87	2.36	1.72	3.48	1.22	2.04	2.46	0.66			1.94
6	3.21	2.81	2.30	1.73	3.40	1.20	2.00	2.38	0.65	1.90		
7	3.25	2.85	2.34	1.72	3.46	1.22	2.03	2.63	0.66	1.93		
8	3.24	3.04	2.76	1.72	3.65	1.17	2.14	2.21	0.71	1.93		
9	3.15	2.99	2.42	1.68	3.78	1.79	2.11	2.49	0.74	1.91		
10	3.30	3.10	2.50	1.80	3.60	1.10	2.20	2.48	1.00	2.10	2.45	2.00
11	2.92	2.63	2.24	1.64	3.26	1.07	2.04	2.10	0.49	1.75		
12	3.20	2.99	2.51	1.81		1.31		2.36	0.68	2.04	2.54	1.83
13	3.22	3.01	2.49	1.97	3.47	1.31	2.18	2.33	0.77	2.06	2.47	1.82
14	3.46	3.31	2.65	1.80		1.43	2.34	2.58	1.02	2.24	2.55	2.04
15	3.43	3.10	2.60	1.71	3.60	1.40	2.30	2.72	1.00	2.20	2.50	2.00
16	3.04	2.85		1.89		1.37		2.25	0.69	1.96	2.35	1.77
17	3.05	2.85	2.40	1.85		1.35	2.05	2.45	0.65	1.95	2.35	1.75
18	3.34	3.14	2.53	1.94		1.32	2.23	2.75	0.91	2.13	2.53	1.92
19	3.55	3.35	2.74	1.52		1.37	2.33	2.63	1.15	2.23	2.54	2.23
20	3.42	3.21	2.61	1.88		1.41	2.31	2.50	1.00	2.21	2.51	2.01
21	3.57	3.36	2.73	1.93	3.85	1.42	2.39	2.61	1.11	2.29	2.60	2.15

SOURCE:
DWR.

C-083801

TABLE II-7

1987-1990 AVERAGE CROP PRICES BY REGION AND CROP
($/Ton Unless Noted)

Region	Irrigated Pasture ($/AUM)	Alfalfa	Sugar Beets	Other Field Crops	Rice	Truck Crops	Tomato	Deciduous Orchard	Small Grains	Grapes	Cotton ($/Bale)	Subtropical Orchard
1	12.0	83.3		97.4				2142.8	99.1			
2	12.0	83.3	36.8	97.4	151.0	370.0		2142.8	99.1			269.3
3	12.0	83.3	36.8	97.4	151.0	370.0	50.9	2142.8	99.1			
3B	12.0	83.3	36.8	97.4	151.0	370.0	50.9	2142.8	99.1			269.3
4	12.0	83.3	36.8	97.4	151.0	370.0	50.9	2142.8	99.1			
5	12.0	83.3	36.8	97.4	151.0	370.0	50.9	2142.8	99.1			269.3
6	12.0	86.9	36.1	102.2	150.0	415.0	52.0	2136.0	103.5	1305.0		
7	12.0	86.9	36.1	102.2	150.0	415.0	52.0	2136.0	103.5	1305.0		
8	12.0	86.9	36.1	102.2	150.0	415.0	52.0	2136.0	103.5	1305.0		
9	12.0	86.9	36.1	102.2	150.0	415.0	52.0	2136.0	103.5	1305.0		
10	12.0	91.0	36.4	116.0	156.0	448.3	52.1	2229.7	108.8	981.5	409.2	327.4
11	12.0	91.0	36.4	116.0	156.0	448.3	52.1	2229.7	108.8	981.5		
12	12.0	91.0	36.4	116.0		448.3		2229.7	108.8	981.5	409.2	327.4
13	12.0	91.0	36.4	116.0	156.0	448.3	52.1	2229.7	108.8	981.5	409.2	327.4
14	12.0	85.8	34.0	106.2		423.0	50.3	2253.0	112.7	823.9	408.0	318.4
15	12.0	85.8	34.0	106.2	150.0	423.0	50.3	2253.0	112.7	823.9	408.0	318.4
16	12.0	85.8		106.2		423.0		2253.0	112.7	823.9	408.0	318.4
17	12.0	85.8	34.0	106.2		423.0	50.3	2253.0	112.7	823.9	408.0	318.4
18	12.0	85.8	34.0	106.2		423.0	50.3	2253.0	112.7	823.9	408.0	318.4
19	12.0	85.6	35.5	106.1		417.9	50.3	2246.1	112.1	1402.5	402.7	334.2
20	12.0	85.6	35.5	106.1		417.9	50.3	2246.1	112.1	1402.5	402.7	334.2
21	12.0	85.6	35.5	106.1	150.0	417.9	50.3	2246.1	112.1	1402.5	402.7	334.2

SOURCE:
County Agricultural Commissioners.

C-083801

TABLE II-8

1987- 1990 AVERAGE CROP YIELD BY REGION AND CROP
(Tons per Acre unless Noted)

Region	Irrigated Pasture (AUM)	Alfalfa	Sugar Beets	Other Field Crops	Rice	Truck Crops	Tomato	Deciduous Orchard	Small Grains	Grapes	Cotton (Bales)	Subtropical Orchard
1	12.0	6.5		4.3				0.6	2.8			
2	12.0	6.5	22.8	4.3	3.9	11.8		0.6	2.8			7.4
3	12.0	6.5	22.8	4.3	3.9	11.8	29.6	0.6	2.8			
3B	12.0	6.5	22.8	4.3	3.9	11.8	29.6	0.6	2.8			7.4
4	12.0	6.5	22.8	4.3	3.9	11.8	29.6	0.6	2.8			
5	12.0	6.5	22.8	4.3	3.9	11.8	29.6	0.6	2.8			7.4
6	12.0	6.8	24.2	4.5	3.8	12.3	30.3	0.6	3.3	1.7		
7	12.0	6.8	24.2	4.5	3.8	12.3	30.3	0.6	3.3	1.7		
8	12.0	6.8	24.2	4.5	3.8	12.3	30.3	0.6	3.1	1.7		
9	12.0	6.8	24.2	4.5	3.8	12.3	30.3	0.6	3.1	1.7		
10	15.0	7.2	27.2	4.3	3.5	12.8	31.5	0.7	3.1	2.1	2.3	10.5
11	15.0	7.2	27.2	4.3	3.5	12.8	31.5	0.7	3.1	2.1		
12	15.0	7.2	27.2	4.3		12.8		0.7	3.1	2.1	2.3	10.5
13	15.0	7.2	27.2	4.3	3.5	12.8	31.5	0.7	3.1	2.1	2.3	10.5
14	15.0	8.1	27.3	4.4		12.8	32.4	0.8	2.8	2.9	2.6	11.6
15	15.0	8.2	27.3	4.4	3.3	12.8	32.4	0.8	3.3	2.9	2.6	11.6
16	15.0	8.2		4.4		12.8		0.8	3.3	2.9	2.6	11.6
17	15.0	8.2	27.3	4.4		12.8	32.4	0.8	3.3	2.9	2.6	11.6
18	15.0	8.2	27.3	4.4		12.8	32.4	0.8	3.3	2.9	2.6	11.6
19	15.0	8.1	27.5	4.9		13.2	34.5	0.8	2.7	2.6	2.5	12.6
20	15.0	8.1	27.5	4.9		13.2	34.5	0.8	2.7	2.6	2.5	12.6
21	15.0	8.1	27.5	4.9	3.3	13.2	34.5	0.8	2.7	2.6	2.5	12.6

SOURCE:
County Agricultural Commissioners.

LEGEND:
AUM = animal unit per month.

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land assessments were obtained from a direct survey of more than 50 Central Valley water districts.

CVPM calculates groundwater costs using information on depth to groundwater, drawdown, and total cost per acre-foot per foot of lift. All three are data inputs that the user can change if desired. The groundwater depths are data inputs to the model. Drawdown is assumed to be affected by the rate of pumping, so that as pumping rates increase, drawdown increases. Due to lack of data for estimation, the model assumes only minor changes in drawdown, with a linear relationship between pumping rate and drawdown. Water price data and current depth to groundwater are provided in Table II-9.

CROP PRODUCTION COSTS

Production costs are based primarily on budgets prepared by Reclamation for its repayment analysis. These budgets were compared to budgets obtained from the University of California Extension Service (various years). Additional detail and an example budget are provided in Attachment B. Crop production cost data appear in Table II-10.

CVPM MODEL STRUCTURE

The CVPM consists of four modules:

- a data file that includes information on irrigated crop production, irrigation water supplies, and other baseline data and parameters;
- an aggregation routine that allows the user to aggregate regions and/or crops as needed;
- the basic set of mathematical relationships that constitute the model; and
- a user-modifiable policy change file that includes output tables to present model results.

An additional file to create additional output tables can also follow the policy change file. Attachment C contains a description of each module and other information about obtaining and operating the model.

TABLE II-9

WATER COST AND PRICE DATA

Region	Local Water Costs		GW Lift (ft)	CVP Project Water	State Water Project
	Per acre	Plus Per acre-foot			
1	$5.00	$28.40	130	$5.90	
2	5.00	3.20	120	11.00	
3	10.00	6.30	85	4.65	
3B	5.00	1.00	110	11.20	
4	7.00	3.80	60	4.65	
5	8.00	6.40	75	4.65	
6	4.00	10.60	70	4.75	
7	1.00	4.10	95	4.75	
8	3.00	7.60	110	6.60	
9	0.00	12.30	80	14.25	
10	2.00	1.00	60	18.30	$30.00
11	10.00	9.10	75		
12	10.00	10.00	90		
13	7.00	10.60	125	19.00	
14	10.00	13.00	350	18.27	100.00
15	0.00	24.10	210	14.15	51.00
16	0.00	4.00	130	14.50	
17	0.00	7.50	130	20.60	
18	0.00	2.70	200	20.80	
19	0.00	35.80	310		51.00
20	5.00	8.60	310	19.40	51.00
21	0.00	34.60	310	14.50	51.00

SOURCE:
Survey of districts, Reclamation (1993, 1994), DWR (various years).

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TABLE II-10

CROP PRODUCTION COST ESTIMATES USED IN THE CVPM

Crop	Variable Cost (per acre)	Fixed Cost (per acre)	Harvest Cost (per ton unless noted)
Alfalfa, Regions 1-10	$85	$150	$9.8
Alfalfa, Regions 11-21	81	162	9.0
Alfalfa seed	446	123	216.7
Almonds	358	230	460.0
Citrus	726	582	32.0
Corn	168	35	12.8
Cotton (Bales)	222	103	115.2
Dry beans	191	34	95.2
Fresh tomatoes	546	182	220.0
Melons	221	98	154.6
Miscellaneous grain	124	19	11.0
Miscellaneous hay	85	18	20.6
Miscellaneous vegetables	1,973	42	174.0
Oil seed	104	30	20.0
Olives	178	174	236.2
Onions	880	14	136.0
Pasture (AUM)	61	58	
Peaches	1,191	255	81.5
Potatoes	630	112	47.2
Prunes	493	330	359.8
Process Tomatoes	597	141	5.2
Raisin Grapes	367	291	173.8
Rice	216	120	30.0
Sugar beets	271	70	4.6
Walnuts	355	319	223.5
Wine grapes	343	279	48.1
Wheat	81	37	22.5

NOTE:
Costs do not include water, irrigation system costs, management or land rent.
SOURCE:
University of California Cooperative Extension Service, USBR crop production budgets

VARIABILITY, RISK, AND UNCERTAINTY

Economists and farmers have long recognized that there are economic costs associated with risk and uncertainty in agricultural production. The CVPIA may influence agricultural decisions through effects on variability, risk, and uncertainty. Risk is created when the future cannot be known with certainty but there is a known probability distribution of potential outcomes. Typically, the probability distribution (mean and variance) is estimated based on historical values. Risk associated with water supplies is a good example. The probability of a critical or dry year type can be estimated based on historical records.

Uncertainty is associated with an unknown probability distribution. The distribution may be unknown because the source of uncertainty has no historical record, or factors are expected to change in a way that cannot be predicted. The uncertainty created by new laws or changing technology are examples.

Several approaches for incorporating risk into the analysis of CVPIA have been considered:

1. Incorporate risk directly as an argument in the producers' objective function. The most widespread approach is to incorporate variability of crop revenue as a cost in the objective function, with an appropriate cost coefficient (called the risk aversion coefficient).

2. Incorporate constraints that reflect risk aversion or downside risk aversion. For example, a constraint can prevent perennial crop acreage from exceeding amount supported by the water supply available in the driest year.

3. Assess impacts for different categories of water delivery (water year types), and show how the pattern of impacts varies between alternatives. One way to do this is to define year types by ranges of water delivery, and then assess the change in probability that water supply will fall in different year types. Another approach is to identify several particular years or sets of years that represent a range of hydrologic conditions. For each year or set of years, estimate how the water delivery changes from the No-Action Alternative compared to an alternative. The cost of adjusting to this change is one measure of the cost of water supply variability.

The analysis of the CVPIA uses a combination of Approaches 2 and 3. Within the CVPM analysis, perennial crop acreage is not allowed to exceed the water supply available during the dry and critically dry period 1928-34. Also, each alternative is assessed for three water year types defined as overall average (1922-90), average dry (1928-34), and average wet (1967-71). Irrigated acreage, water use, value of production, and net income are compared for each year type. In addition to this CVPM analysis, the cost of additional water supply variability is estimated by calculating the cost of well capacity needed to eliminate the additional surface supply shortage in the driest one-, two-, and three-year period.

A number of other effects of and responses to risk are considered in the analysis for the PEIS, but are not estimated quantitatively. These include the following:

- More variability in water supplies leads to more variable net and total farm revenues. This can lead to financial difficulties because annual payments on land and machinery tend to be fixed.

Two approaches that farmers can use to reduce these problems are to reduce fixed financial obligations and to invest in more reliable water supplies and water management.

- More variable production implies more variable crop prices, and the increased variability may diminish overall crop demand, reducing prices. Production becomes more variable to the extent that total water supply is more variable. More variable production creates incentive for risk-averse buyers to shift their purchases to other regions because CVP agriculture cannot guarantee a crop.

- Ability to use water transfers reduces variability and risk associated with water shortage. The CVPIA includes water transfer provisions that may affect the amount and price of water transfers and, subsequently, the cost and variability of all water supplies. The CVPTM water transfer model is used to model quantities and prices of water transfers.

- Water districts have more variable revenues, which can lead to financial difficulties. Like farmers, water districts have fixed payment obligations. Revenues become more variable with water supplies to the extent that services are charged on a per-unit-water delivered basis. More variable water supplies create incentives for districts to use flat fees, land assessments, or other non-price mechanisms.

- A shorter water contract term increases uncertainty about future water supplies.

GROUNDWATER USE

Estimates of groundwater pumping in different regions of the Central Valley vary significantly, depending on source. CVGSM estimates are largely based on 1980 estimates of land use or on DWR 1990 normalized land use. Estimates in DWR's recent Bulletin 160-93 appear to be based on water balance analyses. Estimates made by water districts such as WWD or KCWA also appear to be based on water balance calculations. The CVPM calibration database incorporates a combination of these sources. For analysis of CVPIA alternatives, groundwater use becomes an economic decision within CVPM, subject to long-term capacity of the groundwater resource as estimated in CVGSM.

COST OF GROUNDWATER PUMPED

The cost to pump groundwater includes well development or well deepening cost, the cost of power to pump, and other well O&M. Pumping power cost, in dollars per acre-foot per foot of lift, equals 1.02 x c/PE, where c is the cost per kilowatt-hour (kWh) of power, and PE is the effective efficiency of the well and pump. Thus, at $.08/kWh and a well efficiency of 0.65, pumping power cost is 12.5 cents per acre-foot per foot of lift. Pumping lift is equal to the regional groundwater depth plus effective drawdown.

Additional capital, operation and maintenance costs must be added to the cost of power to pump. The model currently assumes a total variable cost of 20 cents per acre-foot per foot of lift, plus an additional $11 per acre-foot to recover capital costs of well installation.

MODEL CONFIRMATION TESTING

In order to judge the ability of any model or analytical method to make reasonable estimates, models generally are subjected to some kind of testing in which a subset of the available data is used to predict results that can be compared to actual observations. For example, if 10 years of data are available, 8 of these years are used to calibrate the model which is then used to predict results for one of the remaining years. This procedure is variously referred to as model verification, validation, or confirmation. Whereas calibration can be thought of as using the most certain set of data or model parameters to estimate (or simply calculate) the least certain parameters, model confirmation uses the estimated model parameters to predict the values of observed data.

Because CVPM will be used to estimate responses to and impacts of water policy changes, the model was tested by comparing its estimates to actual results from the 1991 and 1992 water years. These years were selected because they allow enough preceding years for calibration and they represent the worst drought conditions. For this testing, an 11 region aggregation of CVPM was used, and the model was run as a short-run analysis using the previous 4 years of acreage data as a base for each of the confirmation runs. So, average acreage and water supply for 1987-1990 formed the calibration base for the short-run 1991 model confirmation and 1988-1991 was the calibration base for 1992. Inputs for the confirmation run included surface water available, expected crop prices (estimated as a weighted lag of current and the previous two years' prices), changes in ARPs and deficiency payments for program crops, and estimates of the crop evapotranspiration of applied water.

One of the major challenges in model testing and confirmation is how to deal with conditions that are not explicitly described in the model but which are different in the calibration period than in the confirmation testing period. An obvious approach is to incorporate all such conditions explicitly in the model, but this is not always realistic or feasible. Agricultural production is the result of interactions among many different physical, biological, and behavioral processes. A model of agricultural production cannot realistically incorporate all of these processes - such a model would be unwieldy. Instead, models must treat some variables and processes as constant and focus on explaining the most important interactions among policy changes and response variables. During model confirmation, the analyst must determine whether differences between model prediction and actual observation are the result of a poorly structured or calibrated model, changes in unmodeled variables, or inaccurate data used for model confirmation.

Some crops exhibited long-term trends in acreage related to shifts in demand. These trends were estimated from the full 10 years of data, and used to shift demand to account for the elapsed time between calibration years and the test year. A number of factors affecting crop mix and production are not explicitly modeled. Important examples are: pest problems, freezes, changes in processing or marketing contracts, and large increases or declines in export demand. Because CVPM does not attempt to model all of these factors, predicted results for particular regions or crops are likely to deviate from observation (even if the model were otherwise valid). The purpose of the confirmation test is to assess whether the direction and aggregate magnitude of change due to reduced water supply is consistent with observation.

Tables II-11 and II-12 present aggregated results for the 11 regions and 12 crops modeled for the 1991 test. In every crop but one, the predicted direction of change from base was the same as observed. The exception was an actual drop in grape acreage by about 12,000 acres which was not predicted by CVPM. The percent difference between predicted and actual was less than 10 percent for all crops except sugar beets, tomatoes, and subtropical orchards. In these cases the model predicted the right direction of change though the predicted magnitude was smaller than observed.

Results by region show a fairly close correspondence. All regions but one agree in direction and approximate magnitude of change. Region 10 actually increased slightly in acreage though CVPM predicted a slight decline. CVPM also predicted that more of the surface water would be replaced with groundwater in Region 9 than apparently occurred, resulting in a predicted decline in acreage of 56,000 acres, or about 30 percent less than the observed decline of 81,000 acres. Valley-wide, the predicted decline is 219,000 acres compared to an observed decline of 204,000 acres.

Results of the 1992 confirmation are reasonably good when comparing by region, but results for the comparison by crop are mixed. Results for 7 of the 12 crop categories are fairly consistent both in direction of change and approximate magnitude, as shown in Table II-13. Although CVPM predicted a decline in sugar beets of about 7,000 acres, actual decline was 46,000 acres. 1992 sugar beet acreage was 25,000 acres lower in 1992 than 1991, and rebounded by about 25,000 acres from 1992 to 1993. Similarly, tomato acreage dropped by about 75,000 acres from 1991 to 1992 and then rebounded by about 46,000 in 1993; CVPM predicted an increase in 1992. It is likely that the 1992 acreage of these two crops resulted from reactions to changes in marketing and processing or from unusual weather patterns, and not directly from water supply conditions.

Alfalfa and cotton acreage correspond well except in the Tulare Lake region, with CVPM over-predicting alfalfa by about 43,000 acres and under-predicting cotton by about 60,000 acres. Because total applied water in the Tulare Basin regions agreed closely between actual and predicted (7,524,000 vs. 7,528,000 acre-feet), the difference in crop mix is likely due to other factors. Additional model confirmation analysis might use different price expectation estimates, for example.

Comparison of results by region in Table II-14 shows that CVPM predicted the direction and approximate magnitude of acreage change consistent with observed change.

TABLE II-11

1991 ACTUAL VS. ESTIMATED ACREAGE BY CROP (Thousand Acres)

Crop Category	Average 1987-90	Actual 1991	Estimated 1991	Actual Change	Predicted Change	Difference % of Actual
Pasture	485	459	427	-25	-58	-7%
Alfalfa	591	613	592	22	1	-4%
Sugar Beets	163	125	154	-37	-9	23%
Other Field	796	747	782	-49	-14	5%
Rice	428	366	392	-62	-36	7%
Truck Crops	356	366	384	10	28	5%
Tomato	256	333	272	78	16	-18%
Deciduous Orchard	872	895	908	23	36	1%
Small Grain	705	610	596	-95	-109	-2%
Grapes	528	517	528	-12	-0	2%
Cotton	1188	1087	1105	-101	-83	2%
Subtropical Orchard	200	245	210	45	9	-14%

TABLE II-12

1991 ACTUAL VS. ESTIMATED ACREAGE BY REGION (Thousand Acres)

Region in 11-Region Model	Average 1987-90	Actual 1991	Estimated 1991	Actual Change	Predicted Change	Difference % of Actual
REG1	177	171	170	-6	-7	-1%
REG2	556	532	513	-24	-42	-4%
REG3	454	432	435	-21	-18	1%
REG4	649	614	614	-35	-35	-0%
REG5	259	243	246	-17	-13	1%
REG6	444	475	472	31	28	-1%
REG7	424	448	438	24	14	-2%
REG8	568	558	560	-11	-9	0%
REG9	518	437	462	-81	-56	6%
REG10	1704	1707	1699	3	-4	-0%
REG11	816	747	739	-69	-76	-1%
Total	6568	6364	6349	-204	-219	-0%

TABLE II-13

1992 ACTUAL VS. ESTIMATED ACREAGE BY CROP (Thousand Acres)

Crop Category	Average 1988-91	Actual 1992	Estimated 1992	Actual Change	Predicted Change	Difference % of Actual
Pasture	477	452	432	-25	-45	-4%
Alfalfa	608	559	613	-49	6	10%
Sugar Beets	149	103	142	-46	-7	37%
Other Field	790	806	782	17	-8	-3%
Rice	420	418	418	-3	-3	0%
Truck Crops	358	366	377	8	19	3%
Tomato	285	261	304	-24	19	16%
Deciduous Orchard	881	908	918	27	37	1%
Small Grain	678	661	609	-18	-69	-8%
Grapes	523	519	522	-4	-1	1%
Cotton	1164	1148	1049	-16	-115	-9%
Subtropical Orchard	212	250	223	38	10	-11%

TABLE II-14

1992 ACTUAL VS. ESTIMATED ACREAGE BY REGION (Thousand Acres)

Region in 11-Region Model	Average 1988-91	Actual 1992	Estimated 1992	Actual Change	Predicted Change	Difference % of Actual
REG1	174	171	170	-4	-4	-0%
REG2	556	550	541	-6	-15	-2%
REG3	452	455	457	3	5	1%
REG4	644	633	621	-11	-23	-2%
REG5	256	242	243	-14	-14	0%
REG6	453	458	461	5	9	1%
REG7	431	449	445	18	14	-1%
REG8	569	557	554	-12	-14	-0%
REG9	500	462	458	-37	-42	-1%
REG10	1710	1705	1686	-5	-24	-1%
REG11	801	770	751	-31	-50	-2%
Total	6546	6452	6388	-94	-157	-1%

CHAPTER III

CVPM APPLICATION TO THE PEIS

Chapter III

CVPM APPLICATION TO THE PEIS

INTEGRATION WITH OTHER ANALYSES

CVPM is implemented as part of an integrated analysis, with surface water hydrology, groundwater, agricultural economics and land use, water transfer analysis, regional economics, and other issue areas transferring information among them. The overall process of analytical integration is discussed in the Analytical Tools Technical Appendix.

Surface water delivery, groundwater pumping and elevations, and agricultural land and water use are interdependent. Traditionally, water operations models assume agricultural land and water use is known, and estimate the available delivery based on that information and on hydrologic conditions. Groundwater pumping estimation uses the assumed water use and surface water delivery and, using a regional water balance, calculates the pumping as a residual (subject to resource capacity or other restrictions). Agricultural production models traditionally treat surface water and groundwater as an available resource, and then select the best acreage, crop mix, and water use.

The analysis of CVPIA impacts attempts to capture interactions between physical and economic phenomena by iterative data transfer between models. A feedback loop, or iteration, between CVPM and CVGSM feeds results of one model back to the other. The analysts must choose where to start and stop the iterative process. For CVPIA, the process started with the hydrologic analysis, which assumed a given land use and irrigation efficiency. Surface water operations models (PROSIM and SANJASM) provided project deliveries to CVGSM. CVPM provided an initial estimate of land use changes resulting from the Land Retirement Program and water acquisition. CVGSM then estimated the groundwater pumping and resulting changes in groundwater storage and elevations. CVGSM processed the information on deliveries, pumping, and elevations and passed the information to the first full implementation of CVPM. Figure III-1 illustrates the process used in the CVPIA analysis.

CVPM processes the information into three water year types, average, dry, and wet. Average is defined as the average delivery for the hydrologic period 1922-90; dry is defined as the average delivery during the drought period 1928-34; and wet is defined as the average delivery during the above normal and wet years 1967-71. In addition, CVPM splits CVP delivery into contract delivery vs. water rights and exchange delivery (which includes base supply under Sacramento River contracts and delivery to San Joaquin River exchange contracts). It also estimates the portion of subregion 3 delivery that is allocated to subregion 3B (Tehama-Colusa subregion).

Based on this initial set of information on delivery, pumping, and change in groundwater elevation, CVPM estimates the irrigated acreage, crop mix, water use by source, and irrigation efficiency. CVPM treats the groundwater pumping estimate from CVGSM as an upper bound on pumping. CVGSM initially assumes that pumping increases or declines to account exactly for

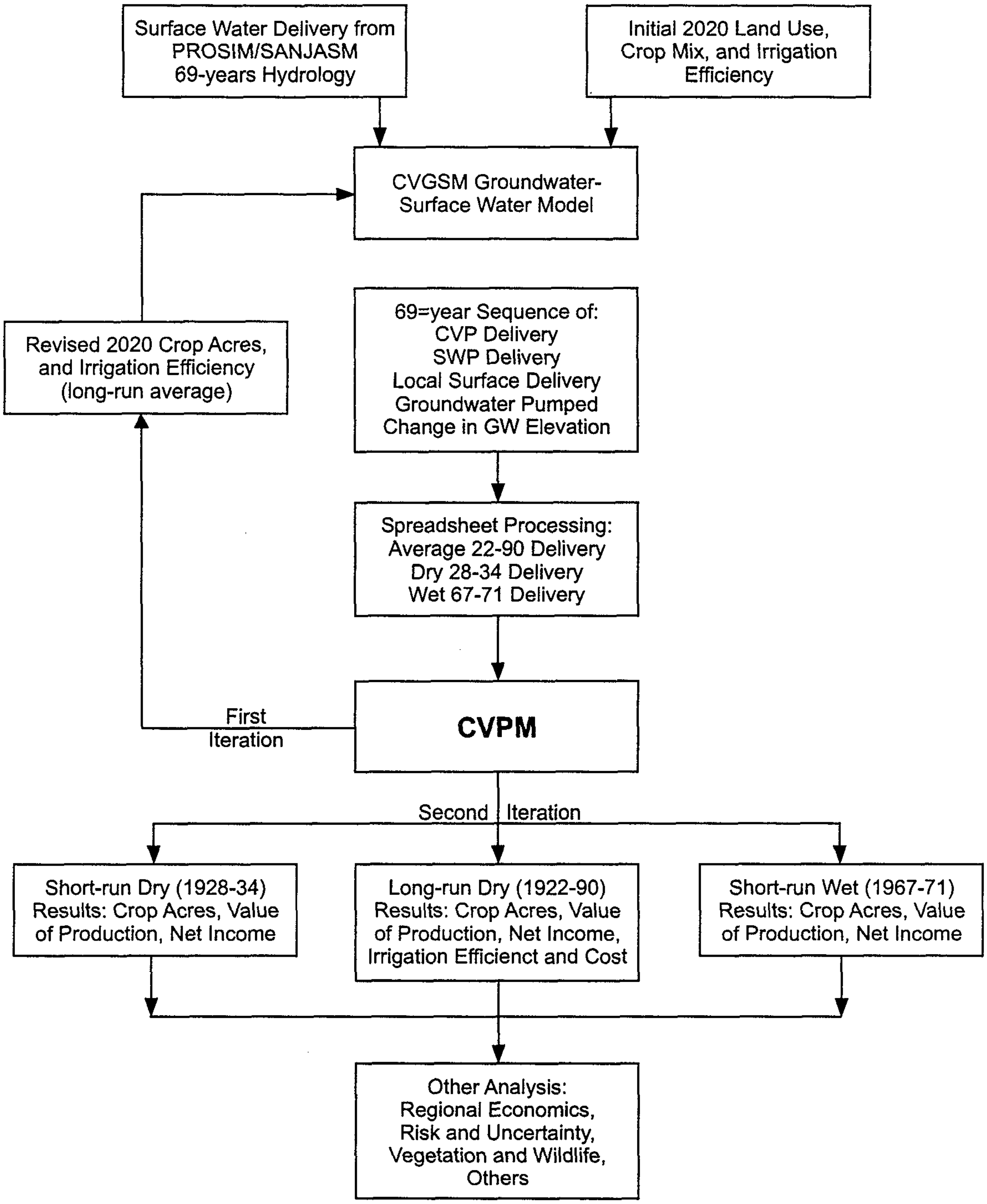

FIGURE III-1

CVPM INTERACTION WITH HYDROLOGY MODELS

changes in surface water delivery. An increase in estimated groundwater pumping is used as an upper bound on pumping in CVPM. If CVGSM estimates a reduction in groundwater pumping, the upper bound in CVPM would not be reduced.

As shown in Figure III-1, irrigated acres by crop and subregion and each subregion's average on-farm application efficiency are fed back for the second iteration of CVGSM. Although not shown in Figure III-1, an intermediate stage in this initial feedback uses the Consumptive Use Model to process new land use and estimate applied water and ET of applied water. CVGSM then re-estimates long-term changes in average groundwater pumping and elevation, and the new estimates are again transferred for the final iteration of CVPM.

Results of CVPM are then submitted for use in other analyses, including Vegetation and Wildlife impacts, and Regional Economic impacts.

IMPLEMENTATION OF PEIS ANALYSIS

This section describes the policy and input changes used to assess each of the alternatives and supplemental analyses. The changes may include a combination of code modifications, data input changes, and built-in model switches.

The discussion is organized by alternative, with the key CVPIA implementation policies described.

NO-ACTION ALTERNATIVE

Following are the important modeling assumptions used for the No-Action Alternative.

- Uses 1987-1990 average conditions as base for calibration.
- Scales crop acreage to match DWR 2020 cropping pattern as starting point.
- Uses DWR Bulletin 160-93 supporting information as basis for ETAW, and for initial AW and irrigation efficiency.
- Uses cost of service rates for CVP project water price (modified as appropriate for ability-to-pay relief).
- Uses No-Action Alternative surface water delivery from hydrology and operations models (processed by CVGSM): 1922-90 average, 1928-34 dry, and 1967-71 wet.
- Uses 2020 groundwater lifts based on CVGSM's No-Action Alternative estimated changes in groundwater elevation from DWR normalized 1990 estimates.
- Uses CVGSM No-Action Alternative groundwater pumping as a starting point and upper bound on pumping.

ALTERNATIVE 1

Assumptions regarding acreage and crop ETAW rates are the same as for the No-Action Alternative. The different implementation assumptions of Alternative 1 focus on three areas:

- Uses tiered water rates plus restoration charges for CVP project water price (modified as appropriate for ability-to-pay relief). Table III-1 contains the estimated CVP water rates, averaged over each subregion, for Existing Condition, No-Action Alternative, and Alternative 1. Table III-1 also shows the rates for two of the supplemental analyses: Analysis 1g with no ability-to-pay policy on water rates; and Analysis 1c using tiered prices that start at full cost rates.

- Uses Alternative 1 surface water delivery from hydrology and operations models (processed by CVGSM). In Alternative 1, the reduction in water supply affects CVP deliveries and is due to the combined impact of dedicated water, Trinity River re-operation, and firm Level 2 refuge supply. Table III-2 compares the net CVP deliveries, measured as on-farm application in CVPM, between the No-Action Alternative and Alternative 1.

- Imposes 30,000 acres of land retirement in westside San Joaquin Valley. Table III-3 lists the assumed distribution of land to be purchased in the Land Retirement Program. This distribution is proportionate to the acreage targeted for retirement by subregion. Actual implementation of the Program may result in a different distribution.

In addition, Alternative 1 uses 2020 groundwater lifts based on CVGSM's Alternative 1 estimated changes in groundwater elevation from DWR normalized 1990 estimates. CVPM also uses CVGSM Alternative 1 groundwater pumping as the starting point and upper bound on pumping.

ALTERNATIVE 2

Assumptions regarding crop acreage, crop ETAW rates, water prices, land retirement, and CVP water management are the same as in Alternative 1. The different implementation assumptions of Alternative 2 focus on two areas:

- Water is acquired from assumed willing sellers in the Sacramento River and San Joaquin River Regions for Level 4 refuge supply. These purchases are already accounted for in the water deliveries received by CVPM.

- Water is acquired from assumed willing sellers in subregions corresponding to the Stanislaus, Tuolumne, and Merced river watersheds for instream flow in these rivers. These purchases are already accounted for in the water deliveries received by CVPM.

In addition, Alternative 2 uses 2020 groundwater lifts based on CVGSM's Alternative 2 estimated changes in groundwater elevation from DWR normalized 1990 estimates. CVPM also uses CVGSM's Alternative 1 groundwater pumping as the upper bound on pumping in subregions with acquired water to prevent groundwater replacement.

TABLE III-1

ESTIMATED CVP WATER RATES, AVERAGED BY SUBREGION
(In 1992 Dollars per Acre-Foot)

CVPM Sub-region	Existing Condition	No-Action	CVPIA ALTERNATIVES: With Ability-To-Pay Tier 1	Tier 2	Tier 3	Without Ability-To-Pay Tier 1	Tier 2	Tier 3	Full Cost Plus With Ability-To-Pay Tier 1	Tier 2	Tier 3
1	5.9	5.9	5.9	14.6	23.4	20.2	28.9	37.6	23.4	26.5	29.6
2	11.0	11.8	11.8	24.7	37.6	31.3	44.1	57.0	37.6	42.6	47.7
3	4.7	2.8	2.8	5.3	7.7	14.1	16.5	19.0	7.7	9.0	10.2
3B	11.2	17.2	17.2	36.2	55.3	28.3	47.4	66.4	55.3	61.3	67.3
4	4.7	5.3	5.3	7.6	9.9	13.8	16.2	18.5	9.9	11.1	12.3
5	4.7	4.5	4.5	7.0	9.4	13.8	16.2	18.7	9.4	10.6	11.8
6	4.8	4.5	4.5	6.8	9.1	14.3	16.6	18.9	9.1	10.3	11.6
7	4.8	6.6	6.6	8.8	11.0	14.3	16.5	18.7	11.0	12.3	13.5
8	6.6	4.5	4.5	7.6	10.6	13.4	16.4	19.4	10.6	11.9	13.2
9	14.3	22.0	28.5	35.2	42.0	28.5	35.2	42.0	42.0	45.5	49.0
10	18.3	27.0	33.5	40.0	46.6	33.5	40.0	46.6	46.6	50.6	54.6
11											
12											
13	19.0	20.2	33.7	39.4	45.1	33.7	39.4	45.1	45.1	48.3	51.5
14	18.3	32.8	39.3	54.4	69.5	39.3	54.4	69.5	69.5	75.8	82.1
15	14.2	21.7	28.2	34.9	41.6	28.2	34.9	41.6	41.6	45.1	48.6
16	14.5	24.8	38.3	44.3	50.3	38.3	44.3	50.3	50.3	53.9	57.6
17	20.6	22.1	35.6	41.9	48.2	35.6	41.9	48.2	48.2	51.7	55.2
18	20.8	21.5	35.0	41.3	47.5	35.0	41.3	47.5	47.5	50.9	54.3
19	51.0	23.2	36.7	42.9	49.1	36.7	42.9	49.1	49.1	52.7	56.2
20	19.4	23.2	36.7	42.9	49.1	36.7	42.9	49.1	49.1	52.6	56.2
19	14.5	22.4	35.4	42.0	48.6	35.9	42.5	49.2	48.6	52.2	55.8

NOTES:
Tiered prices include restoration charges and surcharges.
Existing condition prices are not adjusted for ability-to-pay.
Friant Division tiered prices shown are for Class 1 water.

TABLE III-2

AVERAGE 1922- 1990 CVP WATER DELIVERIES, NO-ACTION ALTERNATIVE AND ALTERNATIVE 1
(Thousand Acre-Feet)

	No-Action Alternative		Alternative 1			
CVPM Subregion	Water Service Contract	Water Rights and Exchange	Tier 1	Tier 2	Tier 3	Water Rights and Exchange
REG1	19.2	95.7	19.2	0.0	0.0	95.8
REG2	32.4	5.4	29.1	0.0	0.0	5.4
REG3	175.2	779.4	146.8	18.4	9.0	774.8
REG3B	200.5	0.0	179.9	0.0	0.0	0.0
REG4	136.4	540.7	136.0	0.0	0.0	539.1
REG5	19.1	0.0	16.0	2.0	2.0	0.0
REG6	2.3	46.8	2.1	0.1	0.0	45.5
REG7	22.0	109.7	22.0	0.0	0.0	109.8
REG8	37.8	0.0	25.8	0.0	0.0	0.0
REG9	37.5	0.0	28.3	0.0	0.0	0.0
REG10	253.6	464.7	186.6	0.0	0.0	446.0
REG11	0.0	0.0	0.0	0.0	0.0	0.0
REG12	0.0	0.0	0.0	0.0	0.0	0.0
REG13	176.2	58.0	133.4	16.7	0.0	58.9
REG14	711.5	0.0	524.7	0.0	0.0	0.0
REG15	41.6	6.9	40.3	0.0	0.0	6.7
REG16	5.2	0.0	16.6	0.0	0.0	0.0
REG17	39.2	0.0	30.7	3.8	0.0	0.0
REG18	401.5	0.0	283.9	35.5	35.5	0.0
REG19	0.0	0.0	0.0	0.0	0.0	0.0
REG20	88.9	0.0	137.6	17.2	17.2	0.0
REG21	109.4	0.0	87.0	10.9	10.9	0.0
Total	2509.4	2107.4	2046.0	104.6	74.5	2081.9

NOTES:
These estimates are of on-farm water delivery.
Friant Division estimates shown include both Class 1 and Class 2 delivery.
Water Rights and Exchange includes base supply under Sacramento River contracts and delivery to San Joaquin River exchange contracts.

TABLE III-3

LAND RETIREMENT PROGRAM ACRES BY SUBREGION

CVPM Subregion	Thousand Acres Retired
10	1.2
14	13.2
15	4.0
19	5.8
21	5.8
Total	30.0

ALTERNATIVE 3

Assumptions regarding crop acreage, crop ETAW rates, water prices, land retirement, and dedicated water are the same as in Alternatives 1 and 2. The additional assumptions of Alternative 3 are:

- Additional (b)(3) water is acquired from assumed willing sellers in subregions corresponding to the Yuba, Mokelumne, Calaveras, Stanislaus, Tuolumne, and Merced River watersheds for instream flow in these rivers. These purchases are already accounted for in the water deliveries received by CVPM.

- (b)(2) and (b)(3) water flowing into the Delta is available for Delta export and delivery to water contractors, if consistent with other environmental restrictions. This assumption is already reflected in surface water delivery estimates provided by the hydrologic models, and is not implemented directly in CVPM.

In addition, Alternative 3 uses 2020 groundwater lifts based on CVGSM's estimated Alternative 3 changes in groundwater elevation from DWR normalized 1990 estimates. CVPM also uses CVGSM's Alternative 1 groundwater pumping as the upper bound on pumping in subregions with acquired water to prevent groundwater replacement.

ALTERNATIVE 4

Assumptions regarding crop acreage, crop ETAW rates, water prices, land retirement, and dedicated water are the same as in Alternatives 1, 2, and 3. The different implementation assumptions of Alternative 4 focus on two areas:

- Water is acquired from assumed willing sellers in the Sacramento River and San Joaquin River regions as in Alternative 3.

- (b)(2) and (b)(3) water is also used to meet Delta water actions presented in preliminary information developed by the AFRP (see Attachment G to the Draft PEIS). This assumption is already reflected in water delivery estimates provided by the hydrologic models. The major agricultural effect is to reduce water delivered to CVP and SWP contractors south of the Delta.

In addition, Alternative 4 uses 2020 groundwater lifts based on CVGSM's Alternative 4 estimated changes in groundwater elevation from DWR normalized 1990 estimates. CVPM also uses CVGSM's Alternative 1 groundwater pumping as the upper bound on pumping in subregions with acquired water to prevent groundwater replacement.

SUPPLEMENTAL ANALYSES

A number of supplemental analyses are also performed using CVPM. Analyses 1a and 1d assess changes in policies affecting water deliveries to agricultural users. CVPM is run using the assumptions for Alternative 1 described above except that hydrologic model results used in CVPM reflect the water delivery changes.

Supplemental Analyses 1e, 1f, 2b, 3a, and 4a assess interregional water transfers, and are described in the Water Transfer Opportunities and CVPTM Technical Appendices. Supplemental Analyses 1c and 2d assess the impact of tiered water pricing starting at full cost for the first 80 percent of contract amount, and increasing in 10 percent increments for the final two blocks. Full-cost-plus tiered water rates are shown on average by region in Table III-1. Supplemental Analysis 1g assesses the impact of no ability-to-pay limits on water prices to CVP users. The tiered rates used for this analysis are also shown in Table III-1. The other Supplemental Analyses are not expected to affect water deliveries or agricultural economics.

CHAPTER IV

BIBLIOGRAPHY

Chapter IV

BIBLIOGRAPHY

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ATTACHMENT A

CVPM TECHNICAL DESCRIPTION

Attachment A

CVPM TECHNICAL DESCRIPTION

The CVPM is a regional agricultural production model developed by DWR. It is a policy tool to assess regional impacts on agricultural production from changes in water (or other resource) supplies, resource pricing, commodity market conditions, and regulatory controls. CVPM simulates the decisions of agricultural producers in the Central Valley of California. The model assumes that farmers act to maximize profits of their enterprises subject to resource constraints, production technology, and market conditions. The model assumes that farmers operate within a competitive market in the sense that no one farmer can affect or control the price of any commodity. Therefore the model's objective function maximizes CPS, defined as the sum of consumers' surplus (net value of the products to consumers) and producers' surplus (profit). CVPM maximizes CPS subject to available land, water from various sources, and three types of economic response functions: a set of commodity demand functions relating total quantity produced to the market price; a set of acreage response functions, relating changes in crop acreage to changes in net returns and other cost information; and a set of functions describing the tradeoff between applied water and irrigation technology.

COMMODITY DEMAND FUNCTIONS AND PRICE FLEXIBILITIES

The CVPM incorporates estimated price flexibilities into linear commodity demand functions. The calibration period price and output is combined with the price flexibility to construct a linear demand function. As output changes due to changes in water policy, the model predicts changes in market price based on the price flexibility.

Price flexibility is defined as the percent change in market price caused by a percent change in output. Price flexibilities must be appropriate to the region being analyzed, in this case the Central Valley. For example, a flexibility estimated for California as a whole must be adjusted for the proportion of California production that occurs in the Central Valley. The CVPM is set up to read in California-wide flexibilities and then adjust them for Central Valley-only flexibilities, using DWR estimates of the proportion of California production that occurs in the Central Valley.

Let F_c be the California-wide estimate of price flexibility for a commodity, defined as the percent change in price per percent change in California production:

$$F_c = (dP_c/dQ_c) \cdot (Q_c/P_c)$$

Then the appropriate price flexibility for Central Valley production is adjusted by the proportion of California production grown in the Central Valley, $k = Q_{cv}/Q_c$. Assume that quantity produced outside the Central Valley is unchanged, so $dQ_c = dQ_{cv}$. In order to simplify the analysis of commodity price changes, the model assumes that the base market price for each commodity is the same across the state, with regional variation accounted for as deviations from the base market price. The commodity demand equations (and therefore the price flexibilities) apply to the base price. If P_c is the base price and m_r is the deviation from the base price in region r, then actual price in region r is $P_{r,c} = P_c + m_r$. To derive the Central Valley price flexibility from the California-wide estimate:

$$F_c = (dP_c/P_c) \cdot (Q_c/dQ_c) = (dP_c/P_c) \cdot (Q_{cv}/dQ_{cv}) \cdot 1/k.$$

Because $P_c = P_{cv}$, the first two terms on the right hand side equal F_{cv}, so solving for F_{cv}:

$$F_{cv} = F_c \cdot k,$$

or the Central Valley price flexibility is equal to the statewide flexibility times the proportion of the commodity grown in the Central Valley.

CVPM uses the baseline conditions of price and quantity along with the estimated Central Valley price flexibility to calculate changes in commodity price caused by a change in quantity produced. The model approximates dP_c as P_c(base) - P_c(new) and dQ_{cv} as Q_{cv}(base) - Q_{cv}(new). Substituting these into the price flexibility equation and solving for P_c(new),

$$P_c(new) = P_c(base) \cdot [1 - F_{cv} \cdot (Q_{cv}(base) - Q_{cv}(new))/Q_{cv}(base)].$$

Existing estimates of California price flexibilities from the agricultural economics literature were used for the model. Commodities that could not be found in existing studies were approximated using values for similar kinds of commodities.

POSITIVE MATHEMATICAL PROGRAMMING

PMP is a technique developed to incorporate both marginal and average conditions into a regional optimization model (Howitt, 1995). Traditional regional models have relied on data based on observed average conditions (e.g., average production costs, yields, and prices). According to economic theory, the short- or long-run equilibrium level of activities is determined by marginal conditions. PMP is a technique whereby information on the marginal value of resources (derived from shadow prices) is used to augment the average cost/revenue information and calibrate a regional model to a baseline condition. This allows the model to predict a more diverse set of activities than would be possible with a simple linear framework.

A number of economic or market conditions can influence the marginal tradeoffs among crops and therefore the observed crop mix.

- Willingness of the market to buy additional amounts of a given commodity (i.e., the commodity demand function) declines as more is produced.
- Risk considerations—crop diversification is a known strategy for reducing downside risk.
- Crop rotations can improve yields or reduce costs.

- Marketing/processing constraints—cotton ginning capacity, for example, may be limited in the short run, although over the long run this would not be limiting.
- Government farm programs may encourage some crops and limit production of others.
- Other resource constraints—restrictions on water, labor, or capital can force a crop mix that does not appear to be the most profitable.

Regional models can accommodate all of these constraints in various ways. Perhaps the most widespread reason for crop diversity is the underlying diversity in growing conditions and market conditions. All farms and plots of land do not produce the same, average set of conditions, and therefore the marginal cost and revenue curves do not coincide with the average cost and revenue curves. A linear programming model based on average costs and returns does not capture this. PMP uses information about the average and the marginal conditions to generate appropriate marginal cost and/or revenue functions that can predict the observed diversity of activities.

To illustrate, consider a two-crop (wheat and cotton) regional production model. Let the average observed net return to wheat be $50 per acre (as estimated from county-wide yields and prices and estimated production cost budgets), and let the average net return to cotton be $100 per acre. With 100 acres of land available, a simple linear programming model would obviously allocate all 100 acres to cotton and none to wheat, based on the average costs and returns. In fact, however, we observe that 40 acres are growing wheat and 60 are growing cotton. In the absence of externalities or other market-distorting considerations, economic theory requires that the equilibrium condition allow the same net return, at the margin, to either crop. Otherwise total net return could be increased by shifting an acre to the crop yielding the greater net return.

In order to create a condition of marginal equality, PMP augments the linear total cost (or revenue) function with quadratic terms that guarantee the marginal equality conditions will hold at the observed crop mix. For the example above, a difference of $50 per acre between marginal and average net return to cotton would explain the apparent suboptimal solution observed. A simple PMP model could add a linear marginal cost of production to cotton such that, at the observed acreage, cotton's average net return is $100 but its marginal net return is only $50. Because the marginal cost is rising, additional cotton acreage beyond its observed level would be less profitable than wheat acreage, while cotton acreage below the observed level would be more profitable than wheat acreage. Under this structure, predicted cotton and wheat acreage would exactly match the observed values.

This simple example can be generalized mathematically. The objective of the standard programming approach is to maximize net revenue, defined as:

$$NR = (py - AC) \bullet X,$$

where p is a vector of prices per unit, y is a vector of yield in units per acre, AC is a vector of average production costs per acre, and X is a vector of acres. This expresses net revenue (NR) in terms of average revenues and costs. PMP augments this linear specification with a nonlinear function of acreage by crop, f(X):

$$NR_A = (py - AC)\ X + f(X).$$

The nonlinear function is quadratic in the case of CVPM. Calculated properly, the augmented, nonlinear objective function can produce the same level of NR as the linear function at the baseline acreage, but can create marginal conditions that also satisfy the profit-maximizing first order conditions at the baseline acreage.

The PMP procedure is mathematically equivalent to adding a nonlinear adjustment cost function onto the linear NR specification, although the rationale and interpretation are quite different.

The variability in marginal NR embodied in the PMP function can represent variation in production cost, variation in yield, variation in crop quality (which affects the crop price), or a combination of all three. These possibilities can be classified into revenue effects (yield and/or price) and production cost effects. Let a, b, and c be parameters of a quadratic revenue function and d, f, and g be parameters of a quadratic cost function. Assuming farmers use the land best suited to a given crop first and expand to less suited land as total production increases, then marginal revenue declines and/or marginal cost increases as X increases, so:

$$b <= 0 \text{ and } g >= 0.$$

Gross revenue becomes $GR = p \bullet y \bullet X + (c + a \bullet X + .5\ b \bullet X^2)$,

and total cost becomes $TC = AC \bullet X + (d + f \bullet X + .5\ g \bullet X^2)$.

Then $NR_A = p \bullet y \bullet X + (c + a \bullet X + .5\ b \bullet X^2) - AC \bullet X - (d + f \bullet X + .5\ g \bullet X^2)$

Marginal net revenue can be broken into average net revenue (which is constant with respect to acreage) and the components of the marginal revenue and marginal cost functions (which exhibit declining marginal net revenue).

$$MNR = p \bullet y - AC + [(a - f) + (b - g) \bullet X] \text{ or}$$

$$MNR = p \bullet y - AC + [\alpha + \beta \bullet X]$$

The PMP approach can attempt to account for the revenue and cost components separately; it can simply combine them and not distinguish whether the parameters represent cost effects or revenue effects; or it can combine them and assume that the marginal function represents either falling marginal revenue or rising marginal cost. Although the choice of assumption does not affect the mathematical form of the net revenue function, it does affect how results of the model are interpreted. For example, if the PMP augmenting function is assumed to represent falling marginal yield, then changes in acreage will affect commodity prices both directly (acreage changes) and indirectly (yield changes), and these effects will somewhat offset each other. Alternatively, if the PMP augmenting function is assumed to represent rising marginal cost, then only the acreage change affects commodity prices.

The CVPM assumes that the marginal function represents increasing marginal production cost. This assumption affects how the PMP parameters, α and β, are estimated. The next section derives the approach used for estimating the PMP parameters.

ACREAGE RESPONSE ELASTICITIES AND PMP COEFFICIENTS

The example in the section above showed how a point estimate of the difference between marginal and average conditions can be used to calibrate a model to observed crop mix. Essentially the calibration condition provides one point on the marginal cost function. Additional assumptions or information are needed to determine the slope of the marginal cost function. The CVPM addresses this need by incorporating acreage response elasticities directly in the linear marginal cost functions. Acreage elasticity is defined as the percent change in acreage of a crop due to a percent change in expected revenue. Basically, this is an acreage supply elasticity with per-acre revenue acting as the unit price received for an acre of production. Because the CVPM will be used primarily to assess long-term, permanent changes in water supply and prices, long-run supply elasticities are generally appropriate. The following derivation can be used with either long-run or short-run elasticities.

The total cost of production in the CVPM objective function includes both an observed cost per acre derived from cost-of-production analyses (denoted AC), and a quadratic component in acreage of crop c. In matrix notation, the total cost for all crops is:

$$C = AC \bullet X + (K \bullet \iota + A \bullet X + .5 \bullet X' \bullet \Gamma \bullet X)$$

where AC is a vector of observable production costs per acre, X is a vector of crop acres, ι is a vector of ones, and K, A, and Γ are parameters of the imputed cost function.

The following derivation of PMP coefficients assumes that Γ is diagonal, i.e., that the total or marginal cost of crop c is unaffected by the acreage of any other crop. This assumption is maintained in CVPM, but could be relaxed if sufficient data were available to estimate off-diagonal (cross-crop) effects. The total cost of crop c is:

$$C_c = AC_c \bullet X_c + (K_c + \alpha_c \bullet X_c + .5 \bullet \gamma_c \bullet X_c^2).$$

Then, $MC_c = AC_c + \alpha_c + \gamma_c \bullet X_c$.

Set MC_c = marginal revenue, $p_c y_c$ and solve for

$$X_c = (p_c y_c - AC_c - \alpha_c)/\gamma_c.$$

Then, $dX_c/d(p_c y_c) = 1/\gamma_c$,

so the acreage elasticity is $e_c = (1/\gamma_c) \bullet (p_c y_c/X_c)$, evaluated at observed X_c, p_c, and y_c.

This shows the relationship between elasticity and γ, which combines with the other conditions needed for calibration to define the quadratic PMP function. The conditions described below must hold at the observed acreage for each crop, X^o:

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1. The exogenously determined acreage supply elasticity determines the slope of the MC function, as derived above: $\gamma_c = 1/e_c \bullet p_c y_c / X_c$.

2. In order to calibrate to observed acreage by crop, the marginal cost of an acre of production must equal the observed portion (AC) plus the unobserved portion, indicated by the shadow price from the calibration model (λ). The shadow price represents the deviation between average and marginal cost. Therefore, using the derivation of MC above:

$$MC_c = AC_c + \lambda_c \text{ implies } \alpha_c = \lambda_c - \gamma_c \bullet X_c = \lambda_c - p_c y_c / e_c$$

3. In order to calibrate to observed production cost and net revenue, the unobserved portion of total cost must equal zero at the observed acreage. Therefore using the total cost notation above:

$TC_c = AC_c \bullet X_c$ implies $K_c + \alpha_c \bullet X_c + .5 \bullet \gamma_c \bullet X_c^2 = 0$,

so, $K_c = -(\lambda_c - p_c y_c / e_c) \bullet X_c - .5(1/e_c \bullet p_c y_c / X_c) \bullet X_c^2$

$= (.5 p_c y_c / e_c - \lambda_c) \bullet X_c$

Cost function parameters calculated in this way are largely governed by exogenously determined acreage response elasticities, with the shadow price information used to shift the intercept of the marginal and total cost functions so that the model calibrates to a particular set of base conditions.

IRRIGATION TECHNOLOGY ADJUSTMENTS

CVPM allows agricultural producers to shift irrigation technology in response to changing conditions. Technology is defined as a combination of irrigation system cost and the associated applied water or irrigation efficiency. Data on irrigation system cost and performance were updated from an earlier study prepared for Reclamation (CH2M HILL, 1991).

For each crop category and region, the feasible technology-management combinations were plotted graphically. Some irrigation systems were clearly inefficient and dominated by at least one other system that could provide similar efficiency at much lower cost or similar cost at a much better efficiency. Such irrigation systems were eliminated from the analysis. The remaining data points were fitted to a Constant Elasticity of Substitution (CES) isoquant, having the form:

$$a \bullet [b \bullet W^{\rho} + (1-b) \bullet IC^{\rho}]^{(1/\rho)} = 1$$

where W is the measure of relative water use, AW/ETAW, and IC is the annual irrigation system cost per acre. The parameters a, b, and ρ were estimated using nonlinear least squares.

In the CVPM, both applied water and irrigation system cost are decision (endogenous) variables. The CES isoquants act as nonlinear constraints in the optimization.

Profit maximizing (or cost minimizing) conditions require that the ratio of water price to irrigation technology price be equal to the ratio of the marginal products of water and irrigation technology. Given an estimate of the isoquant, an observed relative applied water also defines the irrigation system cost. For the model to calibrate (i.e., to replicate the observed applied water), either the price ratio or the isoquant parameters must be adjusted.

For calibrating to observed applied water, the CVPM offers the user four alternatives.

Applied Water Calibration Method 1: One way to adjust the effective price ratio is to calculate the irrigation technology price needed for the observed water use-irrigation technology mix to be cost minimizing. Using the first order conditions for minimizing cost subject to the estimated CES isoquant and then solving for irrigation technology cost gives:

$$\text{ICprice} = \theta \bullet \text{ETAW} \bullet ((1\text{-}b)/b) \bullet (\text{IC/W})^{(-1/\sigma)},$$

where ICprice is the calculated irrigation technology price, θ is the imputed price of water applied to the crop, and σ is the elasticity of substitution.

Applied Water Calibration Method 2: A second way to adjust the effective price ratio is to calculate the water price needed for the observed water use-irrigation technology mix to be cost minimizing. Using the first order conditions for minimizing cost subject to the estimated CES isoquant and then solving for irrigation technology cost gives:

$$\text{Wprice} = (1/\text{ETAW}) \bullet (b/(1\text{-}b)) \bullet (\text{IC/W})^{(-1/\sigma)} - \text{WRprice},$$

where WRprice is regional marginal value of water, and Wprice is a crop-specific imputed value of water.

Applied Water Calibration Method 3: A third way to calibrate CVPM to observed water use is to use the PMP function with cross-products between water use and acreage.

Applied Water Calibration Method 4: A fourth way to calibrate to observed water use is to adjust the parameters of the CES function so that the marginal rate of substitution equals the observed price ratio. The estimated CES substitution parameters are kept but the share and scale parameters (a and b in the CES equation) are calculated to force the marginal optimality condition to hold:

$$b = \theta * \text{ETAW}*(\text{IC/W})^{(-1/\sigma)}/(1+\theta*\text{ETAW}*(\text{IC/W})^{(-1/\sigma)})$$

$$a = 1/(b*W^{\rho} + (1\text{-}b)*IC^{\rho})^{(1/\rho)}$$

All four of these methods have been coded into CVPM and all will calibrate the model to water use, acres, and net revenue. The first two have the advantage of using estimated scale and distribution parameters (rather than calibrated from a single data point), but they require some modification to prices or costs. In cases where water price and/or irrigation system costs are important policy variables, it is believed that the fourth method is preferable because it does not directly modify the observed prices. The version of CVPM used for this analysis uses the fourth method of calibration.

HARVESTED AND IRRIGATED ACRES

CVPM distinguishes between total irrigated acreage, total harvested acreage (including dryland production), and the portion of irrigated acreage that is harvested. The data from the County Agricultural Commissioners reports total harvested acreage and yield. The ratio of total harvested to harvested **and** irrigated acreage is based on Census of Agriculture estimates. Representing this ratio for a given crop as **t**, and the ratio of irrigated yield to harvested crop yield as **s**, the CAC data can be adjusted to reflect only irrigated yields. Overall observed production, Y_O*X_O, is the sum of dryland production and irrigated production:

$$Y_O*X_O = Y_I*X_I + Y_D*X_D \, .$$

Substitute $Y_I = s*Y_D$, $X_I = t*X_O$, and $X_D = (1-t)*X_O$ and solve for Y_I :

$$Y_I = (s*Y_O) / (1-(1-s)*t) \, .$$

SCALING THE MODEL TO 2020 CONDITIONS

One of the assumptions in the analysis for the CVPIA was the use of the year 2020 as the basis for comparison of alternatives. Bulletin 160-93 (DWR, 1994) was used to determine projected land use in 2020. Two problems arose because of this. First, the water supply assumptions of DWR's projections are not consistent with the conditions for the CVPIA No-Action Alternative. Second, Bulletin 160-93 irrigated crop acres were not supported by the economic demands, prices, and costs determined from the calibration database in CVPM. DWR used a demand and supply forecasting procedure to develop 2020 crop acres, and these forecasts estimated significant shifts in demands and supplies between 1990 and 2020. Because of these shifts, production of vegetables and orchards increased while field crops (especially pasture and alfalfa) declined.

In order to provide analysis that is reasonably consistent with DWR projections and yet incorporates the changes in water supply conditions imposed by the CVPIA and the Bay-Delta Accord, a three step procedure is used in CVPM. The first step calibrates the economic parameters to the average 1987-1990 conditions from the calibration database. The second step scales (i.e., shifts) the crop demand and supply functions so that relative prices and costs are maintained as calibrated, but the model approximates the 2020 crop mix projected by DWR. The scaling procedure also maintains the price flexibilities at their estimated values. The third step imposes the changes in water supply conditions and other policies as appropriate for the alternative.

MODEL CONVEXITY

Convexity is a mathematical characteristic of constrained optimization problems that guarantees that any local optimum found by a mathematical search algorithm will also be the global optimum. The mathematical structure of CVPM is constrained optimization, or nonlinear programming, which has the general form:

(NLP) Maximize F(x)
Subject to g(x)=0
h(x)<=0
X>=0.

For CVPM, x is a vector of decision variables: irrigated acres, applied water per acre, irrigation cost per acre, water use by source, and endogenous crop price. A well-known theorem of mathematical programming, the Kuhn-Tucker sufficiency theorem, states that, subject to constraint qualification, if F(x) is concave and g(x) and h(x) are convex (including linear), then any local maximum point is a global maximum point. A local maximum is defined as a point that satisfies the Karush-Kuhn-Tucker first-order maximum conditions. Another theorem, known as the Arrow-Enthoven Theorem states that, if F(x) is quasiconcave over the feasible region and the functions g(x) and h(x) are quasiconvex, then any local maximum of NLP is a global maximum (see for example, Chiang, 1984). Both of these theorems provide sufficient conditions for assuring that a well-designed search algorithm will find a global maximum. Because they are sufficient but not necessary conditions, there exists a potentially large set of NLP structures that may satisfy neither set of conditions yet are convex in the sense that any local maximum is also a global maximum.

In addition, a well-designed search algorithm may consistently find the true global maximum even though the NLP is not globally convex. There is, however, no way of proving that this is so; the appropriate procedure in cases where the NLP cannot be proven convex is to provide a good starting point for the search algorithm, often by first solving a convex approximation of the NLP and by placing reasonable bounds on the feasible set. Global optimality can be further tested by comparing the solution using a number of different starting points.

CVPM maximizes a nonlinear objective function subject to a set of linear constraints (both equality and inequality) and a set of nonlinear equality constraints allowing substitution between irrigation system cost and efficiency. The quadratic terms in the objective function represent increasing marginal cost and declining marginal revenue (for some crops). The Hessian matrix associated with these terms is diagonal and negative semidefinite, therefore this portion of the objective function is easily shown to be concave (and therefore also quasiconcave). If irrigation technology is held constant, the remaining terms of the objective function and all of the constraints would be linear, resulting in a convex model. However, the irrigation technology functions, having the form known as CES, are nonlinear (though convex). The decision variables in these functions, applied water per acre and irrigation cost per acre, also appear as cross product terms with crop acres in the objective function. As a result, proving global optimality of solutions to the model with variable irrigation technology has not yet been possible.

Two strategies are used to improve the likelihood that the solution from a particular model run is a global optimum. First, the policy changes are first implemented in a fixed-technology version of CVPM. As described above, this model version satisfies the sufficient conditions for convexity and global optimality. This provides an excellent starting point for the full, nonlinear solution of CVPM. The second strategy compares the results achieved from the good starting point against results from a number of other starting points. If results are the same for each starting point, then a high probability exists that the result is globally optimal. This was done for each of the main alternatives. Table A-1 illustrates results from an 11-region version of a Preliminary Alternative that was considered but not evaluated further in the PEIS. This discarded alternative is used here because it imposes the greatest change on the model inputs and is probably the most likely to cause numerical difficulty in finding a global optimum. The 11-region results were the same regardless of the starting point used, as was the case for each of the PEIS alternatives.

TABLE A-1

TEST OF DIFFERENT STARTING POINTS

Region	Crop	Different Starting Points				
		Original Solution (1,000 ac)	CHG12 Difference (1,000 ac)	CHG13 Difference (1,000 ac)	CHG14 Difference (1,000 ac)	CHG15 Difference (1,000 ac)
REG1	IRRPAST	20.609	0.000	0.000	0.000	0.000
REG1	ALFHAY	8.507	0.000	0.000	0.000	0.000
REG1	SBEETS	3.300	0.000	0.000	0.000	0.000
REG1	FIELD	14.211	0.000	0.000	0.000	0.000
REG1	RICE1	3.144	0.000	0.000	0.000	0.000
REG1	TRUCK	12.531	0.000	0.000	0.000	0.000
REG1	ORCHARD	77.965	0.000	0.000	0.000	0.000
REG1	GRAIN	11.142	0.000	0.000	0.000	0.000
REG1	SUBTROP	7.263	0.000	0.000	0.000	0.000
REG2	IRRPAST	0.001	0.000	0.000	0.000	0.000
REG2	ALFHAY	6.067	0.000	0.000	0.000	0.000
REG2	SBEETS	18.108	0.000	0.000	0.000	0.000
REG2	FIELD	23.786	0.000	0.000	0.000	0.000
REG2	RICE1	19.080	0.000	0.000	0.000	0.000
REG2	TRUCK	34.139	0.000	0.000	0.000	0.000
REG2	TOMATO	56.605	0.000	0.000	0.000	0.000
REG2	ORCHARD	64.098	0.000	0.000	0.000	0.000
REG2	GRAIN	40.427	0.000	0.000	0.000	0.000
REG2	SUBTROP	0.703	0.000	0.000	0.000	0.000
REG3	IRRPAST	0.001	0.000	0.000	0.000	0.000
REG3	ALFHAY	2.383	0.000	0.000	0.000	0.000
REG3	SBEETS	3.255	0.000	0.000	0.000	0.000
REG3	FIELD	7.960	0.000	0.000	0.000	0.000
REG3	RICE1	40.399	0.000	0.000	0.000	0.000
REG3	TRUCK	5.507	0.000	0.000	0.000	0.000
REG3	TOMATO	1.831	0.000	0.000	0.000	0.000
REG3	ORCHARD	111.170	0.000	0.000	0.000	0.000
REG3	GRAIN	16.569	0.000	0.000	0.000	0.000
REG3	GRAPES	0.151	0.000	0.000	0.000	0.000
REG3	SUBTROP	1.761	0.000	0.000	0.000	0.000
REG4	IRRPAST	0.001	0.000	0.000	0.000	0.000
REG4	ALFHAY	0.001	0.000	0.000	0.000	0.000
REG4	SBEETS	26.920	0.000	0.000	0.000	0.000
REG4	FIELD	0.001	0.000	0.000	0.000	0.000
REG4	RICE1	0.001	0.000	0.000	0.000	0.000

TABLE A-1. CONTINUED

Region	Crop	Different Starting Points				
		Original Solution (1,000 ac)	CHG12 Difference (1,000 ac)	CHG13 Difference (1,000 ac)	CHG14 Difference (1,000 ac)	CHG15 Difference (1,000 ac)
REG4	TRUCK	38.132	0.000	0.000	0.000	0.000
REG4	TOMATO	65.608	0.000	0.000	0.000	0.000
REG4	ORCHARD	37.812	0.000	0.000	0.000	0.000
REG4	GRAIN	37.176	0.000	0.000	0.000	0.000
REG4	GRAPES	10.055	0.000	0.000	0.000	0.000
REG5	IRRPAST	40.323	0.000	0.000	0.000	0.000
REG5	ALFHAY	12.193	0.000	0.000	0.000	0.000
REG5	SBEETS	11.009	0.000	0.000	0.000	0.000
REG5	FIELD	38.365	0.000	0.000	0.000	0.000
REG5	RICE1	3.893	0.000	0.000	0.000	0.000
REG5	TRUCK	13.894	0.000	0.000	0.000	0.000
REG5	TOMATO	12.544	0.000	0.000	0.000	0.000
REG5	ORCHARD	40.989	0.000	0.000	0.000	0.000
REG5	GRAIN	21.501	0.000	0.000	0.000	0.000
REG5	GRAPES	45.775	0.000	0.000	0.000	0.000
REG6	IRRPAST	0.001	0.000	0.000	0.000	0.000
REG6	ALFHAY	0.001	0.000	0.000	0.000	0.000
REG6	SBEETS	8.984	0.000	0.000	0.000	0.000
REG6	FIELD	20.403	0.000	0.000	0.000	0.000
REG6	RICE1	0.001	0.000	0.000	0.000	0.000
REG6	TRUCK	123.206	0.000	0.000	0.000	0.000
REG6	TOMATO	29.563	0.000	0.000	0.000	0.000
REG6	ORCHARD	31.669	0.000	0.000	0.000	0.000
REG6	GRAIN	11.032	0.000	0.000	0.000	0.000
REG6	GRAPES	0.872	0.000	0.000	0.000	0.000
REG6	COTTON1	13.896	0.000	0.000	0.000	0.000
REG6	SUBTROP	0.100	0.000	0.000	0.000	0.000
REG7	IRRPAST	0.001	0.000	0.000	0.000	0.000
REG7	ALFHAY	0.001	0.000	0.000	0.000	0.000
REG7	SBEETS	0.001	0.000	0.000	0.000	0.000
REG7	FIELD	0.001	0.000	0.000	0.000	0.000
REG7	RICE1	0.001	0.000	0.000	0.000	0.000
REG7	TRUCK	6.751	0.000	0.000	0.000	0.000
REG7	TOMATO	0.001	0.000	0.000	0.000	0.000
REG7	ORCHARD	59.999	0.000	0.000	0.000	0.000
REG7	GRAIN	0.001	0.000	0.000	0.000	0.000
REG7	GRAPES	1.945	0.000	0.000	0.000	0.000

TABLE A-1. CONTINUED

Region	Crop	Different Starting Points				
		Original Solution (1,000 ac)	CHG12 Difference (1,000 ac)	CHG13 Difference (1,000 ac)	CHG14 Difference (1,000 ac)	CHG15 Difference (1,000 ac)
REG7	COTTON1	0.001	0.000	0.000	0.000	0.000
REG7	SUBTROP	0.805	0.000	0.000	0.000	0.000
REG8	IRRPAST	0.001	0.000	0.000	0.000	0.000
REG8	ALFHAY	10.305	0.000	0.000	0.000	0.000
REG8	SBEETS	3.710	0.000	0.000	0.000	0.000
REG8	FIELD	38.536	0.000	0.000	0.000	0.000
REG8	RICE1	0.375	0.000	0.000	0.000	0.000
REG8	TRUCK	19.717	0.000	0.000	0.000	0.000
REG8	TOMATO	5.683	0.000	0.000	0.000	0.000
REG8	ORCHARD	118.707	0.000	0.000	0.000	0.000
REG8	GRAIN	50.967	0.000	0.000	0.000	0.000
REG8	GRAPES	88.299	0.000	0.000	0.000	0.000
REG8	COTTON1	34.589	0.000	0.000	0.000	0.000
REG8	SUBTROP	9.989	0.000	0.000	0.000	0.000
REG9	IRRPAST	0.001	0.000	0.000	0.000	0.000
REG9	ALFHAY	0.001	0.000	0.000	0.000	0.000
REG9	SBEETS	3.229	0.000	0.000	0.000	0.000
REG9	FIELD	9.967	0.000	0.000	0.000	0.000
REG9	TRUCK	148.730	0.000	0.000	0.000	0.000
REG9	TOMATO	58.943	0.000	0.000	0.000	0.000
REG9	ORCHARD	21.758	0.000	0.000	0.000	0.000
REG9	GRAIN	9.714	0.000	0.000	0.000	0.000
REG9	GRAPES	6.176	0.000	0.000	0.000	0.000
REG9	COTTON1	70.654	0.000	0.000	0.000	0.000
REG9	SUBTROP	1.006	0.000	0.000	0.000	0.000
REG10	IRRPAST	18.875	0.000	0.000	0.000	0.000
REG10	ALFHAY	130.748	0.000	0.000	-0.002	0.000
REG10	SBEETS	5.999	0.000	0.000	0.000	0.000
REG10	FIELD	203.422	0.000	0.000	-0.002	0.000
REG10	RICE1	0.072	0.000	0.000	0.001	0.000
REG10	TRUCK	44.250	0.000	0.000	0.000	0.000
REG10	TOMATO	2.708	0.000	0.000	0.000	0.000
REG10	ORCHARD	175.165	0.000	0.000	0.000	0.000
REG10	GRAIN	157.082	0.000	0.000	-0.001	0.000
REG10	GRAPES	252.737	0.000	0.000	0.000	0.000
REG10	COTTON1	390.264	0.000	0.000	-0.003	0.000
REG10	SUBTROP	144.036	0.000	0.000	0.000	0.000

TABLE A-1. CONTINUED

Region	Crop	Different Starting Points				
		Original Solution (1,000 ac)	CHG12 Difference (1,000 ac)	CHG13 Difference (1,000 ac)	CHG14 Difference (1,000 ac)	CHG15 Difference (1,000 ac)
REG11	IRRPAST	0.001	0.000	0.000	0.000	0.000
REG11	ALFHAY	7.122	0.000	0.000	0.000	0.000
REG11	SBEETS	9.097	0.000	0.000	0.000	0.000
REG11	FIELD	18.165	0.000	0.000	0.000	0.000
REG11	RICE1	0.001	0.000	0.000	0.000	0.000
REG11	TRUCK	188.964	0.000	0.000	0.000	0.000
REG11	TOMATO	2.356	0.000	0.000	0.000	0.000
REG11	ORCHARD	112.207	0.000	0.000	0.000	0.000
REG11	GRAIN	9.397	0.000	0.000	0.000	0.000
REG11	GRAPES	71.928	0.000	0.000	0.000	0.000
REG11	COTTON1	116.732	0.000	0.000	0.000	0.000
REG11	SUBTROP	45.385	0.000	0.000	0.000	0.000

NOTES:
- CHG12 Change from AVA5, using starting point at 50% of base acres
- CHG13 Change from AVA5, using starting point at 120% of base acres
- CHG14 Change from AVA5, using starting point at maximum achievable efficiency
- CHG15 Change from AVA5, using starting point at low irrig. efficiency (AW 10% higher than base)

ATTACHMENT B

ESTIMATION AND SOURCES OF ECONOMIC PARAMETERS USED IN CVPM

Attachment B

ESTIMATION AND SOURCES OF ECONOMIC PARAMETERS USED IN CVPM

PRICE FLEXIBILITIES

A survey of existing literature was conducted to obtain the price flexibility estimates provided in Table II-1. Not all crops were represented in the literature, and much of the available literature is somewhat dated. Therefore, some crops were grouped into categories (such as fresh vegetables) with a consistent flexibility assigned to the category. Flexibilities estimated for California as a whole were adjusted to apply to the Central Valley, using the valley's proportion of statewide production, as described in Attachment A.

Wheat, miscellaneous grains, and corn are given price flexibilities of zero in the CVPM: there is no farm-level price response to quantity produced in the Central Valley. The reason for this is that California production of these crops is a small share of total production. Rice and cotton are given only small flexibilities of -0.05 for the same reasons. There is some response because both commodities are produced partially for specialized export markets in which California production can affect price. Sugar beet production also occurs for a national market but is affected by local milling capacity. A small value of -0.10 is used in the CVPM.

No usable empirical information was available for most field and forage crops. Pasture, miscellaneous hay, dry beans, alfalfa seed, and oil seed crops were all assigned a price flexibility of -0.2. Several empirical studies (Knapp, 1990, for example) suggest that alfalfa should be given a higher flexibility. A value of -0.5 is used in the CVPM.

For vegetables, important information was obtained from Nuckton (1980) and King, Adams, and Johnston (1978). Both studies suggest that California vegetable price flexibilities are generally small. King, Adams, and Johnston (1978) estimated a flexibility of -0.12 to -0.13 for fresh tomatoes. For onions, they estimated a flexibility of -0.18. For crops in the miscellaneous vegetable group they estimated lettuce flexibilities of -0.10 to -1.39, depending on season of sale. For carrots, values ranged from -0.11 to -0.58. For cantaloupe, they provide flexibilities of -0.19 to -0.38, depending on season of sale. The CVPM uses a value of -0.2 for all of these vegetable groups (fresh tomatoes, onions, melons, and miscellaneous vegetables).

For potatoes, King, Adams, and Johnston (1978) estimated a California flexibility of -0.45 to -1.03 depending on season of sale. Nuckton's review shows flexibilities of -0.65 to -1.24. The CVPM uses a value of -0.5. For processing tomatoes, one 1975 study estimated a flexibility of -0.27. The CVPM uses a value of -0.25.

Tree fruit and vine crops have generally showed higher price flexibilities. For pears, Masud, O'Rourke, and Harrington (undated) found price flexibilities of -1.67 and -0.94 for fresh market and processing pears, respectively. Nuckton's (1978) most recent price flexibilities from the literature and the flexibilities used in the CVPM are summarized in Table B-1.

TABLE B-1

ORCHARD AND VINE CROP PRICE FLEXIBILITIES

	Literature Value	Used in CVPM
Plums and prunes	-0.63 to -1.13	-0.80
Walnuts	-0.25	-0.25
Almonds	-0.49	-0.50
Peaches	-0.36 to -0.63	-0.50
Oranges	-0.89	-0.80
Olives	-0.40	-0.50
Grapes	-0.98	-0.80

ACREAGE RESPONSE ELASTICITIES

Acreage response elasticities were estimated using cross sectional time series for the years 1985 through 1992. Each crop was estimated using a partial adjustment model. The form of the estimation equation was:

$$\ln(AC_t) = a + b(\ln AC_{t-1}) + c(\ln GR_{t-1}) + d(\ln W_t)$$

where

AC is acreage,
AC_{t-1} is acreage lagged one year,
GR_{t-1} is lagged per acre gross revenue,
W_t is surface water supply, and
a,b,c and d are estimated coefficients.

The partial adjustment specification implies that acreage decisions are based on a geometric lag in observed revenues and water supplies. Because current year revenues are not yet realized when cropping decisions are made, the initial value in the gross revenue series is lagged and therefore predetermined. Both long-run and short-run acreage response elasticities can be estimated from this specification. The short-run elasticity is the partial response to a change in the most recent observed revenue, whereas the long-run elasticity captures the full adjustment over time to a permanent change in revenue. Due to the lagged gross revenue and acreage variables, only 7 years were available for estimation. Results are provided in Table II-1 of this technical appendix.

County Agricultural Commissioners do not report the unit value of pasture, so its acreage elasticity could not be estimated. In the CVPM, pasture is assigned the same short- and long-run values (0.24 and 0.51, respectively) as estimated for alfalfa. Although accurate estimates were not available, it is recognized that a significant portion of irrigated pasture in the Central Valley is associated with small pastures and ranchettes, whose purpose is residential and recreational (primarily horse pastures). Because these uses are likely to be relatively unresponsive to changes in market conditions (compared to commercial operations), the overall elasticity for pasture is adjusted downward. For purposes of analysis, it is assumed that half the pasture acreage has a long-run acreage response elasticity similar to alfalfa (0.51) and half has a value of 0.1 (very inelastic), for an overall value of 0.30. Similarly, a short-run elasticity of .15 is used.

For oil seed and alfalfa seed, a short-run and long run elasticity of 0.34 is used in the CVPM corresponding to the long-run value estimated for safflower, an oil seed crop. Potatoes, miscellaneous vegetables, and sugar beets were all given short- and long-run response elasticities of 0.11 and 0.19, respectively, which were the values estimated for onions. The regression estimates for cotton were not significant, so elasticity estimates for cotton were obtained from Duffey et. al (1987).

For tree and vine crops, estimates from the above model were not expected to be as reliable because of the long delay between planting decisions, production, and revenue. Therefore, tree and vine acreage response elasticities were estimated using a longer time series. Data on bearing and non-bearing acreage, yields and prices were obtained from the California Agricultural Statistics Service for the years 1978 through 1992. Bearing and non-bearing acreage were added together to get total acreage. With the lagged variables and some missing data in 1992, 14 observations were generally available. The natural logarithm of each observation was used in the estimation.

Estimated coefficients generally showed the expected signs, but neither the own-price nor the revenue variable were significant for almonds, walnuts, prunes, olives, or wine grapes. One or the other was significant for peaches, oranges, and raisin grapes.

CROP BUDGET ANALYSIS

A crop budget analysis was prepared to estimate the variable and fixed production costs for the selected crops in the model. Crop production cost information was obtained from the University of California Cooperative Extension Service county crop budgets, Reclamation crop budgets prepared for the CVP Cost Allocation Study (March 1992) and updated for this study, California Department of Water Resources existing input into CVPM plus supplemental survey data on crop costs, and cost estimates included in the California Agricultural Resources Model. This information was then compiled on a crop by crop basis. These cost estimates were then reviewed with Reclamation and DWR to select the most representative costs for a given crop. The costs reflect typical growing conditions and typically sized farms for each crop but do not necessarily represent average conditions in a statistical sense.

In general, the farm budgets prepared by Reclamation were selected as the basis for the production cost estimates. Other sources were used if Reclamation budgets were not available for the crop or crop variety. Fixed costs were calculated using Reclamation farm budget instructions. Table B-2 shows the variable and fixed cost information for each crop. It should be noted that the fixed costs do not contain any land rents, interest, or opportunity cost; therefore, net returns represent returns to land and water. Also, irrigation costs are accounted for separately so are not included. Variable costs are further separated into pre-harvest and harvest costs, which vary by subregion based on yield. This cost information was then compiled with price, yield, water use, and irrigation cost data to reflect net returns to water.

IRRIGATION TECHNOLOGY AND COST

Irrigation technology is represented in CVPM by functional relationships between irrigation efficiency and irrigation system cost. The nonlinear functions were estimated from irrigation system performance data prepared as an update to earlier work by CH2M HILL (1991). The updated study, "Irrigation Cost and Performance" (CH2M HILL, 1994), estimated irrigation costs and performance characteristics (including irrigation efficiency) for 8 crop categories, 15 irrigation systems, 3 management levels, and 3 regions within the Central Valley. Not all combinations of these parameters were investigated—some combinations such as drip irrigation on grain or linear-move sprinklers on orchards simply are not sensible and were excluded. Also, some crop categories were not included in the study, so the crops most similar to these in irrigation practices were used. For example, orchard technologies were used for vineyards and alfalfa hay technologies were used for pasture.

For each crop category and region, the feasible technology-management combinations were plotted graphically. Any irrigation system that was clearly inferior was eliminated from the analysis. (A dominant system could provide similar efficiency at much lower cost or similar cost at a much better efficiency.) The remaining data points were fitted to a CES isoquant using nonlinear least squares. The functional form for a CES isoquant is described in Attachment A. Each data point was assumed to produce equivalent yield normalized at 1 acre. Figures B-1 through B-7 show results for eight crops.

TABLE B-2

SUMMARY OF PRODUCTION COST DATA USED IN CVPM

I. VARIABLE COST

Region	Crop	Crop Budget	Source	Pre-Harv. Variable Costs ($)	Harvest Cost ($)				Total Variable Costs ($)
					Costs/ Unit	Units	Yield	Total Harvest	
Sac Valley	Alfalfa		USBR	233.55	9.84	ton	6.2	61.0	294.55
San Joaquin	Alfalfa		USBR	229.55	9.03	ton	7.2	65.0	294.55
Valley-wide	Alfalfa Seed		CARMCVP	445.82	216.67	ton	0.3	65.0	510.82
Valley-wide	Almonds		USBR	446.48	0.23	lb	1,104.0	254.3	700.78
Valley-wide	Citrus	Oranges	USBR	1,038.93	32.00	ton	11.0	352.0	1,038.93
Valley-wide	Field Corn		USBR	213.65	12.84	ton	3.8	48.8	262.45
Valley-wide	Cotton		USBR	311.19	0.24	lb	1,063.0	250.9	562.09
Valley-wide	Dry Beans		USBR	237.06	4.76	cwt	18.0	85.6	322.66
Valley-wide	Fresh Tomatoes		CE, Stanislaus	546.00	3.52	box	1,040.0	3,662.0	4,208.00
Valley-wide	Melon	Mixed Melon	USBR	324.75	7.73	cwt	196.0	1,515.5	1,840.25
Valley-wide	Misc Grain	Barley, dbl crp	CE, Fresno	124.34	11.00	ton	2.5	27.5	151.84
Valley-wide	Misc Hay	Oat Hay	CE, Fresno	85.03	20.63	ton	3.5	72.2	157.23
Valley-wide	Misc Veg	Peppers	CE, Fresno	1,973.00	174.00	ton	13.0	2,262.0	4,235.00
Valley-wide	Oilseed	Safflower	CE, Glenn	104.30	0.01	lb	1,750.0	20.0	124.30
Valley-wide	Olives		USBR	361.70	236.22	ton	3.2	755.9	1,117.60
Valley-wide	Onions	Dry Onions	CE, Imperial	879.85	3.40	sacks	800.0	2,720.0	3,599.85
Valley-wide	Pasture		USBR	118.26		acre			118.26
Valley-wide	Peaches		USBR	1,290.72	81.48	ton	14.3	1,165.2	2,455.92
Valley-wide	Potato	White Potatoes	CE, Fresno	630.00	2.36	cwt	500.0	1,182.0	1,812.00
Valley-wide	Prunes	Prunes, French	CE, Tulare	493.00	359.75	ton	4.0	1,439.0	1,932.00
Valley-wide	Process Tomatoes		CE,Fresno	596.49	5.15	ton	33.0	170.0	766.49
Valley-wide	Raisins, Grape		USBR	454.79	173.79	ton	1.9	330.2	784.99
Valley-wide	Rice		USBR	370.97	0.51	cwt	225.0	113.9	484.87
Valley-wide	Sugar Beets		USBR	337.74	4.60	ton	27.4	126.1	463.84
Valley-wide	Walnuts		CE, Tulare	354.58	223.50	ton	2.0	447.0	801.58
Valley-wide	Wine, Grapes		USBR	434.67	48.10	ton	8.4	404.0	838.67
Valley-wide	Wheat	dbl crp	USBR	120.92	22.56	ton	2.5	56.4	177.32

LEGEND:
CE = University of California Cooperative Extension Service.
CARMCVP = California Agricultural Resource Model, modified to analyze CVP water contracting.
dbl crp = Double cropped.

TABLE B-2. CONTINUED

II. FIXED COST ASSUMPTIONS AND FIXED COST DATA

Assumptions						
Equipment		Establishment				
Debt/Asset Ratio	Interest Rate	Debt/Asset Ratio	Interest Rate	Return on Equity	Depreciation Sinking Fund	Equipment Life (yr)
52.10%	12.02%	12.18%	13.33%	3.40%	6.00%	20

Fixed Cost Data						
Region	Crop	Crop Budget	Source	Capital Cost ($)	Establishment Costs ($)	Stand Life (yr)
Sac Valley	Alfalfa		USBR	795	295	5
San Joaquin	Alfalfa		USBR	795	283	4
Valley-wide	Alfalfa Seed		CARMCVP	527	185	3
Valley-wide	Almonds		USBR	511	2,400	20
Valley-wide	Citrus	Oranges	USBR	2,771	4,900	30
Valley-wide	Field Corn		USBR	328		
Valley-wide	Cotton		USBR	970		
Valley-wide	Dry Beans		USBR	320		
Valley-wide	Fresh Tomatoes		CE, Stanislaus	1,711		
Valley-wide	Melon	Mixed Melon	USBR	925		
Valley-wide	Misc Grain	Barley, dbl crp	CE, Fresno	179		
Valley-wide	Misc Hay	Oat Hay	CE, Fresno	167		
Valley-wide	Misc Veg	Peppers	CE, Fresno	400		
Valley-wide	Oilseed	Safflower	CE, Glenn	284		
Valley-wide	Olives		USBR	600	2,100	40
Valley-wide	Onions	Dry Onions	CE, Imperial	129		
Valley-wide	Pasture		USBR	545		
Valley-wide	Peaches		USBR	540	2,700	20
Valley-wide	Potato	White Potatoes	CE, Fresno	1,051		
Valley-wide	Prunes	Prunes, French	CE, Tulare	690	4,000	25
Valley-wide	Process Tomatoes		CE,Fresno	1,326		
Valley-wide	Raisins, Grape		USBR	530	3,200	20
Valley-wide	Rice		USBR	1130		
Valley-wide	Sugar Beets		USBR	658		
Valley-wide	Walnuts		CE, Tulare	533	5,000	40
Valley-wide	Wine, Grapes		USBR	560	3,000	20
Valley-wide	Wheat	dbl crp	USBR	345		

LEGEND:
CE = University of California Cooperative Extension Service.
CARMCVP = California Agricultural Resource Model, modified to analyze CVP water contracting.
dbl crp: = double cropped.

TABLE B-2. CONTINUED

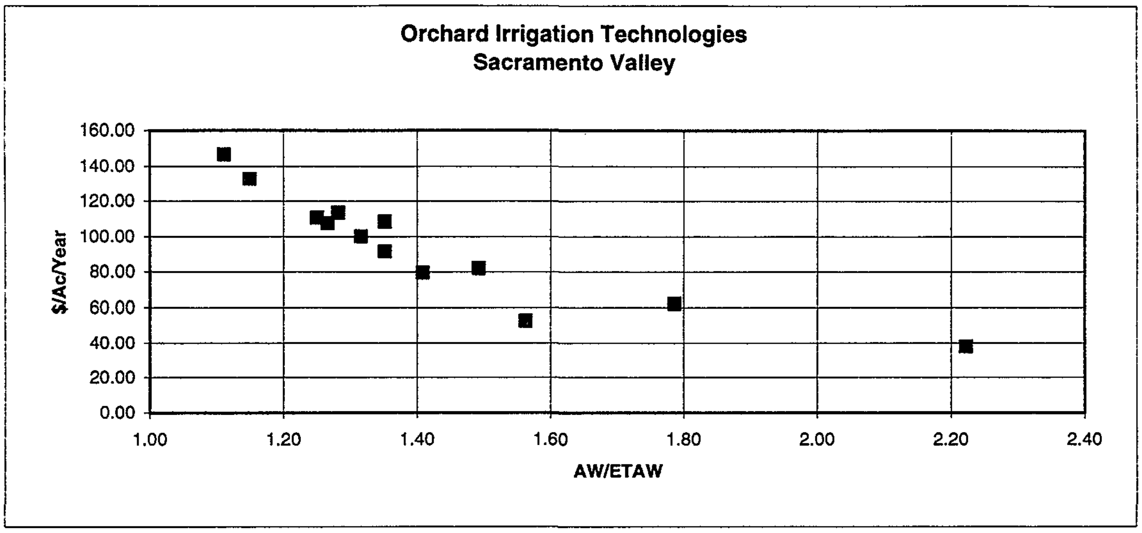
III. FIXED COST CALCULATIONS AND TOTAL VARIABLE AND FIXED COSTS

Region	Crop	Crop Budget	Source	Fixed Cost Calculations ($)							TOTAL
				Depreciation		Interest on Debt		Return on Equity		Total Fixed	Variable &
				CAP	ECAP	CAP	ECAP	CAP	ECAP	Costs	Fixed Costs
Sac Valley	Alfalfa		USBR	21.61	52.33	49.79	4.79	12.95	8.81	150.28	**444.83**
San Joaquin	Alfalfa		USBR	21.61	64.69	49.79	4.59	12.95	8.45	162.08	**456.63**
Valley-wide	Alfalfa Seed		CARMCVP	14.33	58.11	33.00	3.00	8.58	5.52	122.55	**633.37**
Valley-wide	Almonds		USBR	13.89	65.24	32.00	38.97	8.32	71.66	230.08	**930.86**
Valley-wide	Citrus	Oranges	USBR	75.33	61.98	173.53	79.56	45.13	146.31	581.83	**1,620.76**
Valley-wide	Field Corn		USBR	8.92	0.00	20.54	0.00	5.34	0.00	34.80	**297.25**
Valley-wide	Cotton		USBR	26.37	0.00	60.75	0.00	15.80	0.00	102.91	**665.00**
Valley-wide	Dry Beans		USBR	8.70	0.00	20.04	0.00	5.21	0.00	33.95	**356.61**
Valley-wide	Fresh Tomatoes		CE, Stanislaus	46.51	0.00	107.15	0.00	27.87	0.00	181.53	**4,389.53**
Valley-wide	Melon	Mixed Melon	USBR	25.15	0.00	57.93	0.00	15.06	0.00	98.14	**1,938.39**
Valley-wide	Misc Grain	Barley, dbl crp	CE, Fresno	4.87	0.00	11.21	0.00	2.92	0.00	18.99	**170.83**
Valley-wide	Misc Hay	Oat Hay	CE, Fresno	4.54	0.00	10.46	0.00	2.72	0.00	17.72	**174.95**
Valley-wide	Misc Veg	Peppers	CE, Fresno	10.87	0.00	25.05	0.00	6.51	0.00	42.44	**4,277.44**
Valley-wide	Oilseed	Safflower	CE, Glenn	7.72	0.00	17.79	0.00	4.63	0.00	30.13	**154.43**
Valley-wide	Olives		USBR	16.31	13.57	37.57	34.10	9.77	62.70	174.03	**1,291.63**
Valley-wide	Onions	Dry Onions	CE, Imperial	3.51	0.00	8.08	0.00	2.10	0.00	13.69	**3,613.54**
Valley-wide	Pasture		USBR	14.82	0.00	34.13	0.00	8.88	0.00	57.82	**176.08**
Valley-wide	Peaches		USBR	14.68	73.40	33.82	43.84	8.79	80.62	255.15	**2,711.07**
Valley-wide	Potato	White Potatoes	CE, Fresno	28.57	0.00	65.82	0.00	17.12	0.00	111.51	**1,923.51**
Valley-wide	Prunes	Prunes, French	CE, Tulare	18.76	72.91	43.21	64.94	11.24	119.44	330.49	**2,262.49**
Valley-wide	Process Tomatoes		CE,Fresno	36.05	0.00	83.04	0.00	21.60	0.00	140.68	**907.17**
Valley-wide	Raisins, Grape		USBR	14.41	86.99	33.19	51.96	8.63	95.55	290.72	**1,075.71**
Valley-wide	Rice		USBR	30.72	0.00	70.77	0.00	18.40	0.00	119.89	**604.76**
Valley-wide	Sugar Beets		USBR	17.89	0.00	41.21	0.00	10.72	0.00	69.81	**533.65**
Valley-wide	Walnuts		CE, Tulare	14.49	32.31	33.38	81.18	8.68	149.29	319.33	**1,120.91**
Valley-wide	Wine, Grapes		USBR	15.22	81.55	35.07	48.71	9.12	89.58	279.25	**1,117.92**
Valley-wide	Wheat	dbl crp	USBR	9.38	0.00	21.61	0.00	5.62	0.00	36.60	**213.92**

LEGEND:
CE = University of California Cooperative Extension Service.
CARMCVP = California Agricultural Resource Model, modified to analyze CVP water contracting.
dbl crp = Double cropped.
CAP = capital cost.
ECAP = Establishment cost.

C-083847

C-083847

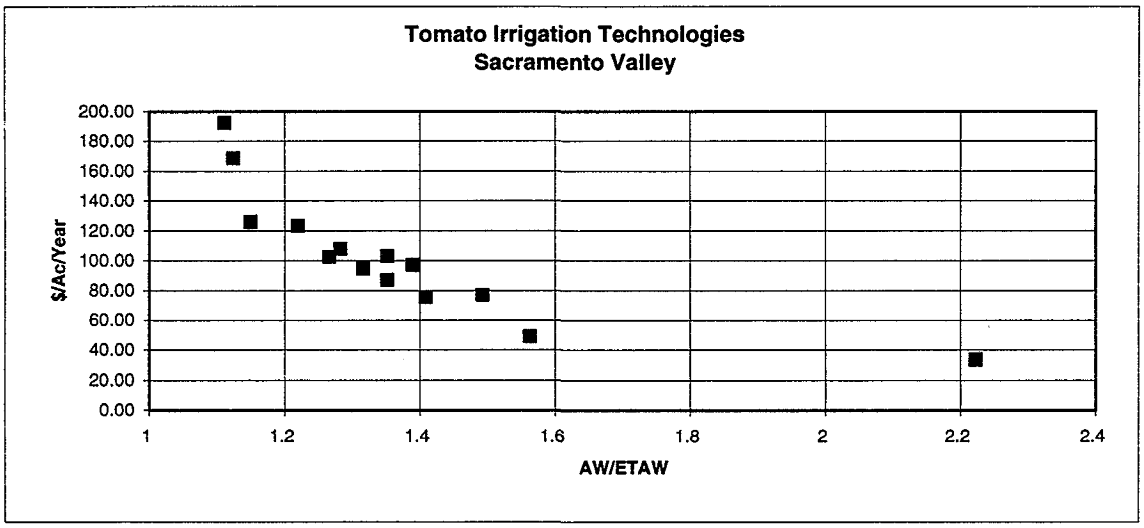


Estimated Isoquant:

$a \cdot [b \cdot (AW/ETAW)^p + (1-b) \cdot (ICcost)^p]^{1/p} = 1$

CES Parameter Estimates

p =	-0.266	F statistic =	3458.7
b =	0.422	Elasticity of	
a =	0.114	Substit. =	0.790



Estimated Isoquant:

$a \cdot [b \cdot (AW/ETAW)^p + (1-b) \cdot (ICcost)^p]^{1/p} = 1$

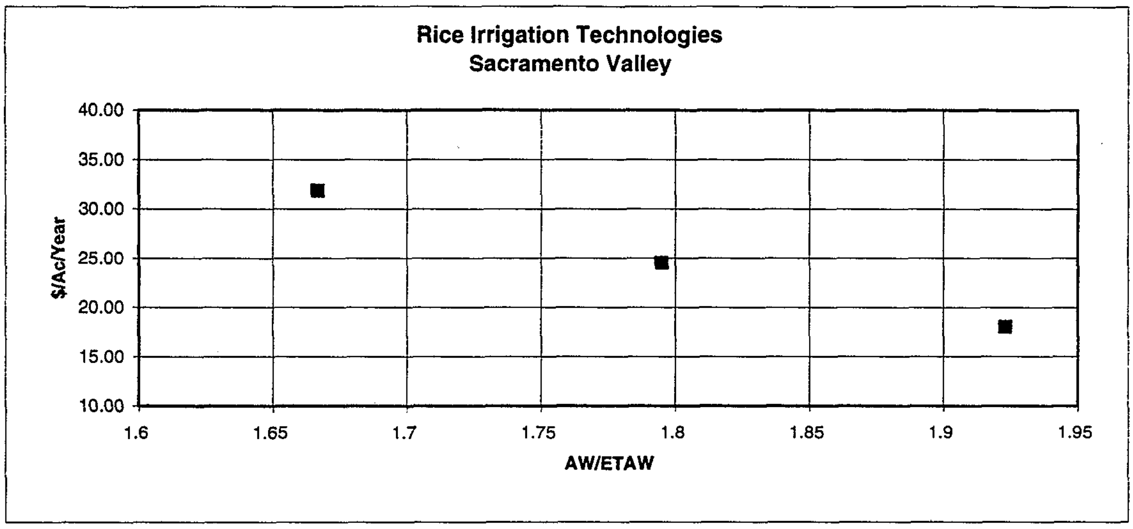
CES Parameter Estimates

p =	-0.494	F statistic =	4412.1
b =	0.273	Elasticity of	
a =	0.096	Substit. =	0.669

FIGURE B-1
ANNUAL IRRIGATION SYSTEM COST AND RELATIVE WATER USE
SACRAMENTO VALLEY, ORCHARD AND TOMATO CROPS

C-083848

C-083848

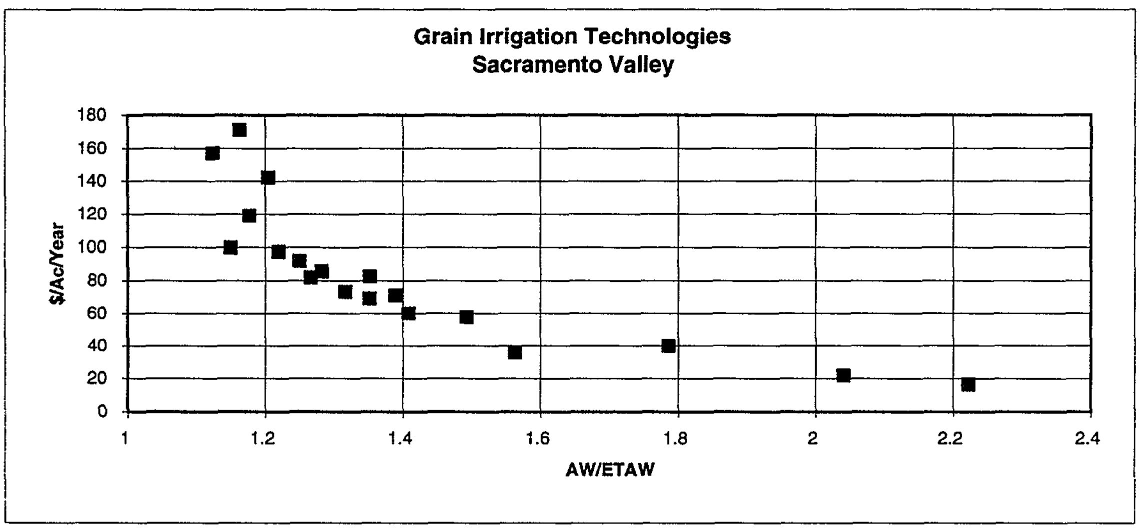


Estimated Isoquant:

$a \cdot [b \cdot (AW/ETAW)^{p} + (1-b) \cdot (ICcost)^{p}]^{1/p} = 1$

CES Parameter Estimates

p =	0.416	F statistic =	NA
b =	0.921	Elasticity of	
a =	0.395	Substit. =	1.712



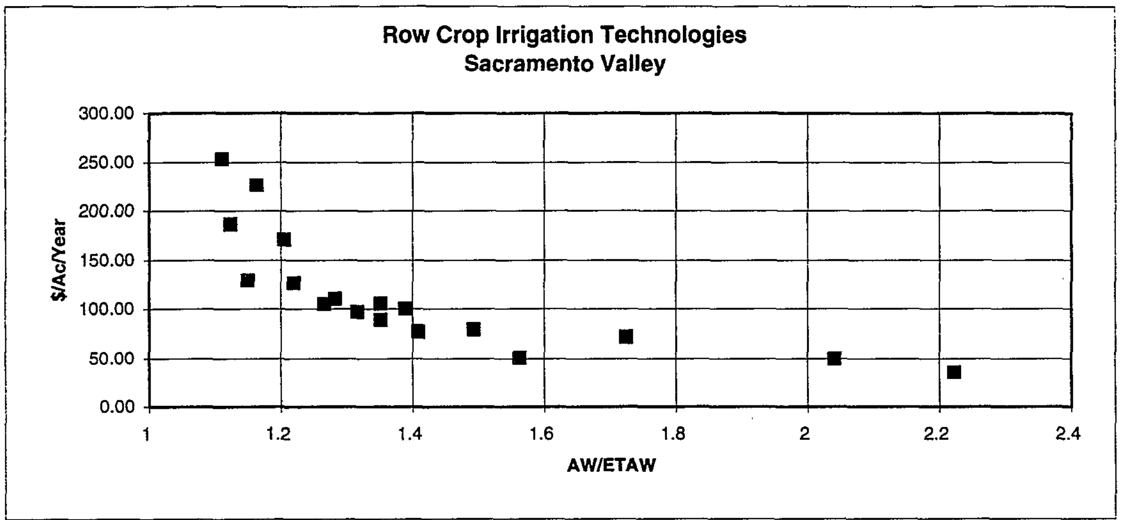
Estimated Isoquant:

$a \cdot [b \cdot (AW/ETAW)^{p} + (1-b) \cdot (ICcost)^{p}]^{1/p} = 1$

CES Parameter Estimates

p =	-0.265	F statistic =	5517.5
b =	0.567	Elasticity of	
a =	0.212	Substit. =	0.791

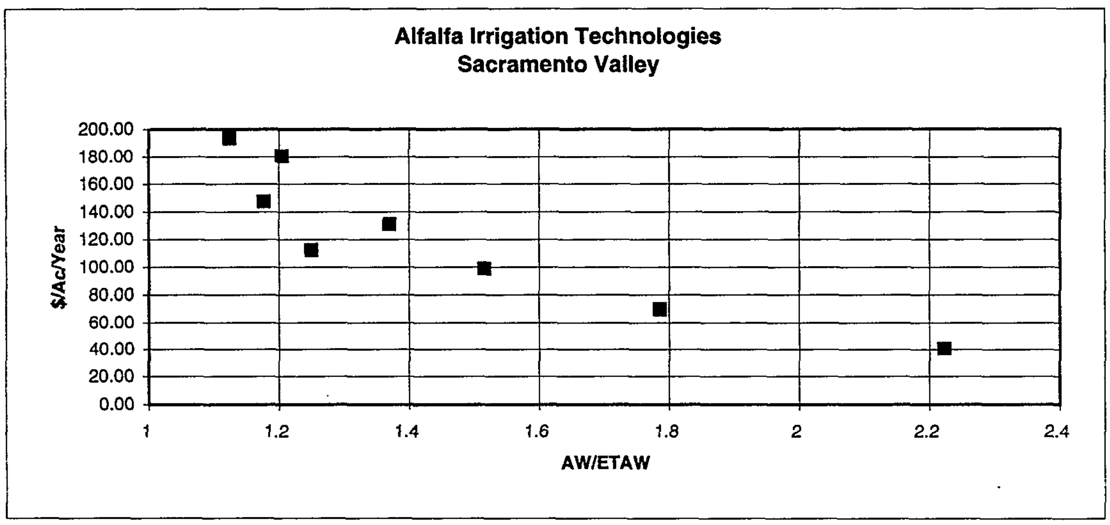
FIGURE B-2
ANNUAL IRRIGATION SYSTEM COST AND RELATIVE WATER USE
SACRAMENTO VALLEY, RICE AND GRAIN CROPS



Estimated Isoquant:
$a\cdot[b\cdot(AW/ETAW)^{p} + (1\text{-}b)\cdot(ICcost)^{p}]^{1/p} = 1$

CES Parameter Estimates

p =	-0.702	F statistic =	2637.6
b =	0.133	Elasticity of	
a =	0.062	Substit. =	0.587

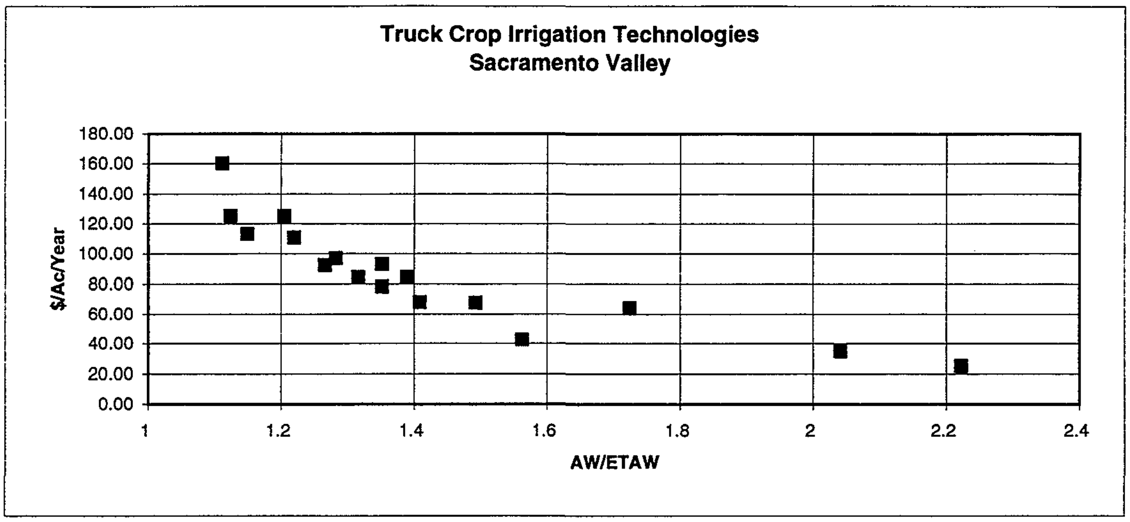


Estimated Isoquant:
$a\cdot[b\cdot(AW/ETAW)^{p} + (1\text{-}b)\cdot(ICcost)^{p}]^{1/p} = 1$

CES Parameter Estimates

p =	-0.129	F statistic =	1284.5
b =	0.570	Elasticity of	
a =	0.145	Substit. =	0.886

FIGURE B-3
ANNUAL IRRIGATION SYSTEM COST AND RELATIVE WATER USE
SACRAMENTO VALLEY, SELECTED CROPS

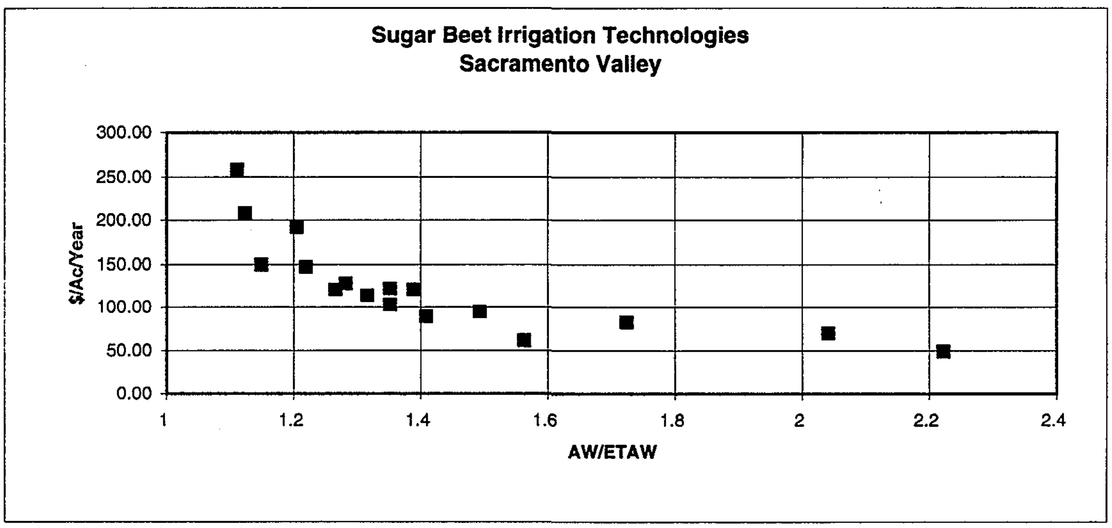


Estimated Isoquant:

$a \cdot [b \cdot (AW/ETAW)^p + (1-b) \cdot (ICcost)^p]^{1/p} = 1$

CES Parameter Estimates

p =	-0.118	F statistic =	3040.7
b =	0.614	Elasticity of	
a =	0.189	Substit. =	0.895



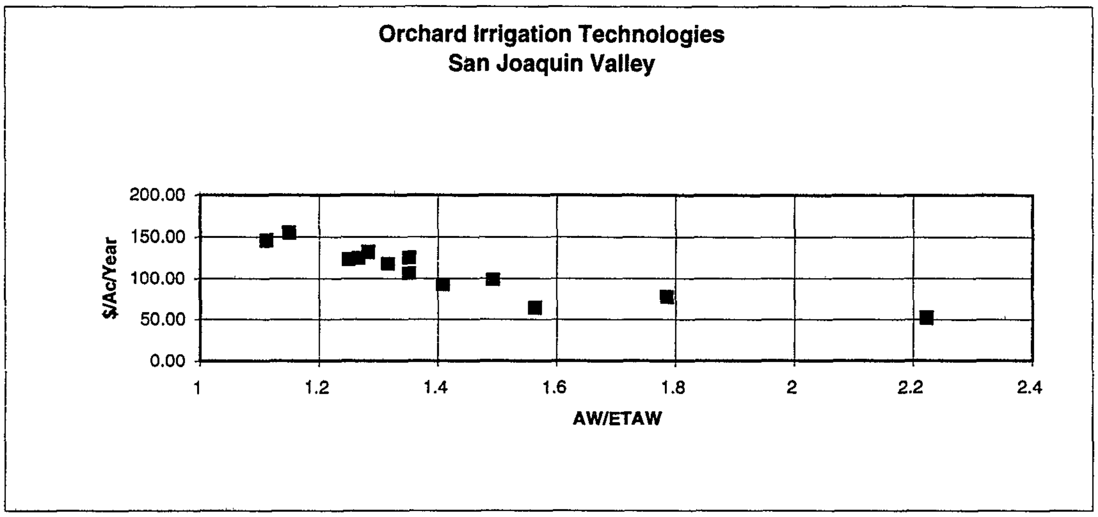
Estimated Isoquant:

$a \cdot [b \cdot (AW/ETAW)^p + (1-b) \cdot (ICcost)^p]^{1/p} = 1$

CES Parameter Estimates

p =	-0.798	F statistic =	2192.4
b =	0.070	Elasticity of	
a =	0.040	Substit. =	0.556

FIGURE B-4
ANNUAL IRRIGATION SYSTEM COST AND RELATIVE WATER USE
SACRAMENTO VALLEY, SELECTED CROPS

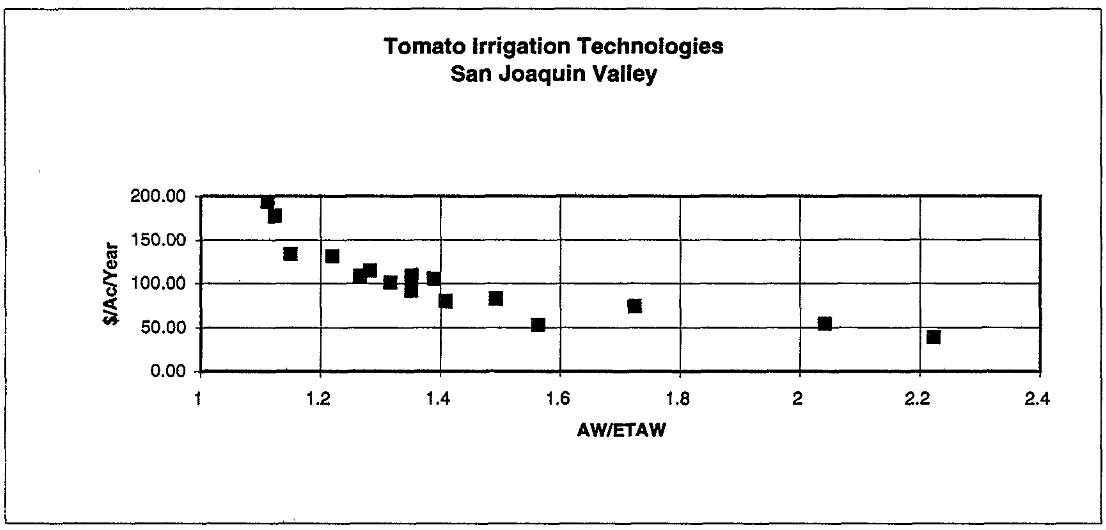


Estimated Isoquant:

$a \cdot [b \cdot (AW/ETAW)^p + (1-b) \cdot (ICcost)^p]^{1/p} = 1$

CES Parameter Estimates

p =	-0.392	F statistic =	2622.0
b =	0.259	Elasticity of	
a =	0.068	Substit. =	0.718



Estimated Isoquant:

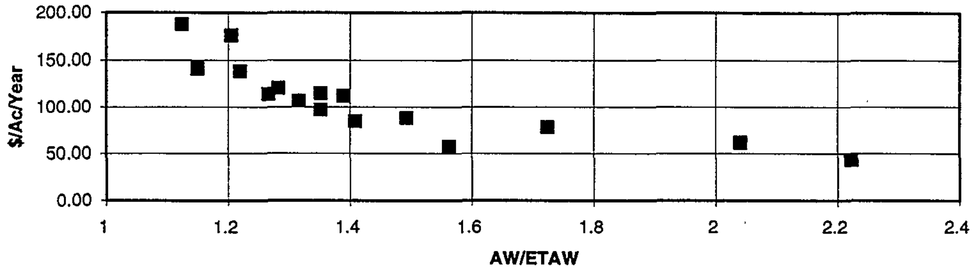
$a \cdot [b \cdot (AW/ETAW)^p + (1-b) \cdot (ICcost)^p]^{1/p} = 1$

CES Parameter Estimates

p =	-0.449	F statistic =	2437.2
b =	0.263	Elasticity of	
a =	0.081	Substit. =	0.690

FIGURE B-5
ANNUAL IRRIGATION SYSTEM COST AND RELATIVE WATER USE
SACRAMENTO VALLEY, SELECTED CROPS

Cotton Irrigation Technologies
San Joaquin Valley



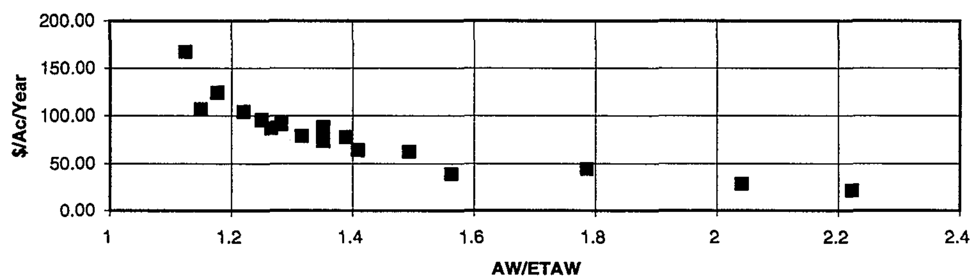
Estimated Isoquant:

$a \cdot [b \cdot (AW/ETAW)^p + (1-b) \cdot (ICcost)^p]^{1/p} = 1$

CES Parameter Estimates

p =	-0.561	F statistic =	2142.3
b =	0.176	Elasticity of	
a =	0.061	Substit. =	0.641

Grain Irrigation Technologies
San Joaquin Valley



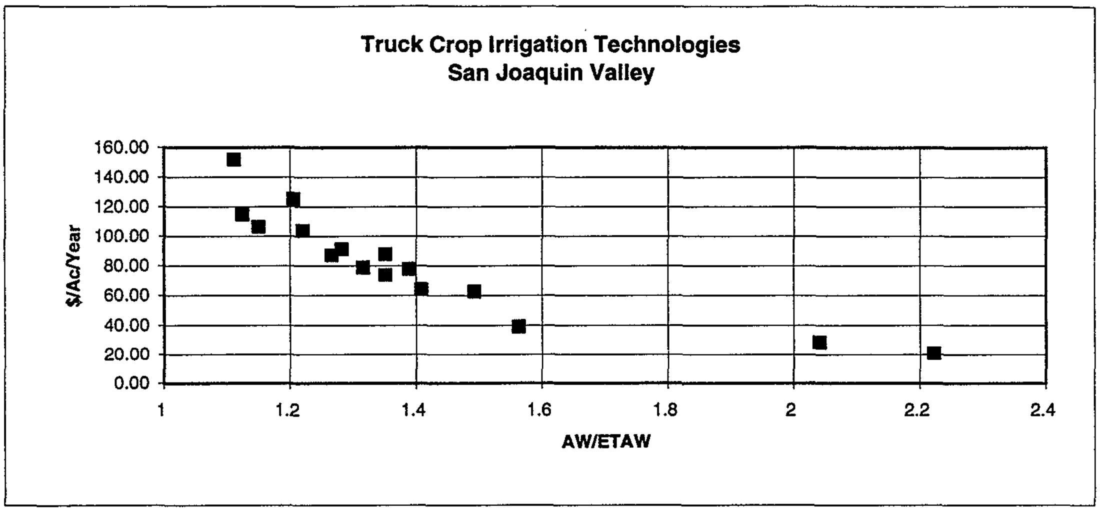
Estimated Isoquant:

$a \cdot [b \cdot (AW/ETAW)^p + (1-b) \cdot (ICcost)^p]^{1/p} = 1$

CES Parameter Estimates

p =	-0.215	F statistic =	5631.1
b =	0.564	Elasticity of	
a =	0.190	Substit. =	0.823

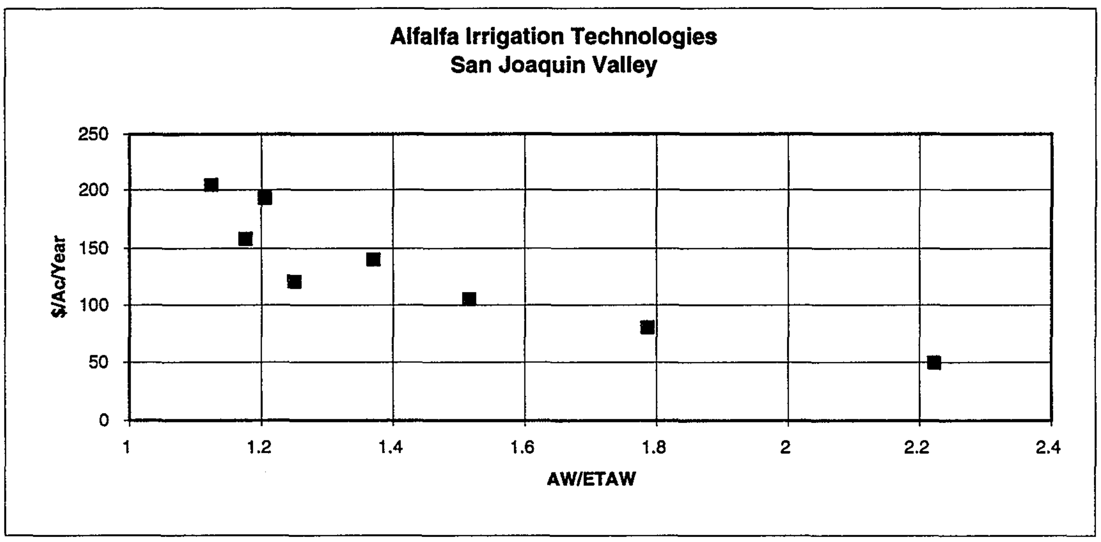
FIGURE B-6
ANNUAL IRRIGATION SYSTEM COST AND RELATIVE WATER USE
SACRAMENTO VALLEY, SELECTED CROPS



Estimated Isoquant:
$a \cdot [b \cdot (AW/ETAW)^p + (1-b) \cdot (ICcost)^p]^{1/p} = 1$

CES Parameter Estimates

p =	-0.217	F statistic =	5344.4
b =	0.561	Elasticity of	
a =	0.190	Substit. =	0.822



Estimated Isoquant:
$a \cdot [b \cdot (AW/ETAW)^p + (1-b) \cdot (ICcost)^p]^{1/p} = 1$

CES Parameter Estimates

p =	-0.247	F statistic =	1251.9
b =	0.419	Elasticity of	
a =	0.098	Substit. =	0.802

FIGURE B-7
ANNUAL IRRIGATION SYSTEM COST AND RELATIVE WATER USE
SAN JOAQUIN VALLEY, SELECTED CROPS

ATTACHMENT C

USING THE CVPM

Attachment C

USING THE CVPM

INTRODUCTION

The CVPM operates using the General Algebraic Modeling System®, or GAMS software. This software is available for DOS-based personal computers (386 processor minimum) and a variety of workstations or larger computers. The CVPM code is portable across all of these platforms.

DATA MODULE

CVPM includes a database of agricultural information for the period 1985 through 1992. This period spans years of full water supply, restricted water supply, and severe drought. Data have been collected from the Reclamation, DWR, water districts, County Agricultural Commissioners, Agricultural Stabilization and Conservation Service, and numerous other sources and organized in simple tables. The column and row headings of the tables are the set descriptors defined for the model. For example, irrigated acreage is entered in a table with years as the column headings and region-crop pairs as the row headings. In the example shown below, the acreage of wheat, miscellaneous grain, and rice grown in Region 1 (R1) is shown in thousands of acres for the years 1985-1992.

		85	86	87	88	89	90	91	92
R1	. WHEAT	1.16	1.46	1.13	1.06	1.10	1.78	0.94	0.90
R1	. MISCGRN	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
R1	. RICE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Most data tables have comments explaining what they contain, and the set descriptors are, in most cases, easy to decipher.

AGGREGATION MODULE

The basic data set for the CVPM defines 26 crop categories and 22 regions within the Central Valley. The nonlinear model may require a substantial amount of time to solve, depending on the speed of the computer and the numbers of crops and regions used. Larger models require exponentially longer times to solve, and the possibility of the algorithm having numerical difficulties also increases. In many cases, a smaller number of aggregated regions or a smaller number of crop categories may be sufficient for purposes of analysis.

For these reasons, the CVPM is set up to allow easy aggregation into smaller numbers of crops and/or regions. The user can aggregate in any way desired, though only sensible aggregations should be used. For example, non-contiguous regions and crops with dissimilar growing conditions and practices (e.g., rice and citrus) should not be aggregated. When aggregating crops, the user must decide which crop within a category should be used as the proxy for the entire category. A number of aggregation modules have already been written, including a 12 crop - 22 region, a 12 crop - 11 region, and a 12 crop - 5 region.

MODEL DESCRIPTION MODULE

The CVPM actually includes two optimization models. A constrained calibration model is used to calibrate the CVPM to a user-defined subset of the data and to estimate shadow price information to be used in the Positive Mathematical Programming (PMP) model. The PMP model replaces some of the constraints with nonlinear functions that use the shadow price information from the calibration model.

Acreage and crop price are endogenous (decision) variables, but yield per acre is not; CVPM does not currently allow for deficit irrigation or other changes in production practices that would affect yield, nor does it assume that the PMP function represents yield differences. Applied water can be adjusted, but the model restricts the adjustment to fall along a constant-yield curve (an isoquant). Along the isoquant, improved irrigation technology (increased irrigation system cost) can substitute for applied water. Crop yield and ETAW are held constant.

Water supplies are identified by source in the CVPM, and the model selects the amount of water to use from among the available sources in the region.

The endogenous variables are shown below as they are defined in the model code.

```
VARIABLES         XN(R,C)          LAND ALLOCATION
                  WAT(R,W)         REGIONAL WATER USE BY SOURCE
                  P(C)             ENDOGENOUS PRICE BY COMMODITY
                  WATAPP(R,C)      ENDOGENOUS APPLIED WATER PER ACRE
                  IRCST(R,C)       ENDOGENOUS IRRIGATION SYSTEM COST
                  BASEPROF         BASELINE PROFIT;
```

The equations forming the calibration model are listed below.

```
EQUATIONS         SOURCE(R,W)      WATER SOURCE CONSTRAINT
                  RESOURCEW(R)     CONSTRAINED WATER RESOURCES
                  RESOURCEL(R)     CONSTRAINED LAND RESOURCES
                  CALCROPU(R,C)    UPPER CALIB CONSTRAINT ON CROP BY REGION
                  CALCROPL(R,C)    LOWER CALIB CONSTRAINT ON CROP BY REGION
                  CESTECH1(R,C)    CES ISOQUANT EQUATION FOR WATAPP AND IRCST
                  CESTECH2(R,C)    COBB DOUGLAS ISOQUANT FOR WATAPP AND IRCST
                  IRRAPP(R,C)      CALIBRATION CONSTRAINT FOR WATER
                                   APPLICATION PER ACRE
                  PRICE(C)         PRICE EQUATION
                  BPROFIT          OBJECTIVE FUNCTION
                  PROFIT           CES PROFIT DEFINITION
```

CALIBRATION MODEL

The calibration model maximizes the sum of producer surplus, i.e., net farm revenue, plus consumer surplus associated with crop demand. The first term in the objective function represents net revenue, which equals yield times price minus irrigation system cost minus non-irrigation-related variable costs per acre, all multiplied by acres, minus water costs by source. The final term is consumer surplus. LR is a binary parameter set to equal 1 for a long-run equilibrium model or 0 for a short-run model.

The equations forming the calibration model are shown below.

```
BPROFIT = SUM((R,C), (YLD(R,C)*(P(C)+PREMIUM(R,C)+(.08+LR*.92)*DEFPMT(R,C))
    - HA2IA(R,C)*IRCST(R,C) - PCOST(R,C,'PHVAR') - LR*PCOST(R,C,'FIXED')
    - PCOST(R,C,'HVAR')*YLD(R,C) - ACOHD(R)) * XN(R,C)$XACRE(R,C))
    - SUM((R,W), (PWAT(R,W) + AFOHD(R,W)) * WAT(R,W))
    - SUM(R,WELLCOST*WAT(R,'GW'))
    - SUM(R,PUMPCOST*DRD(R)*.5*(WAT(R,'GW')/GWPB(R)-1)*WAT(R,'GW'))
    + SUM(C, -.5*FLEX(C)*PBASE(C)/MRKTDAT(C,'BASEQ')
                  * SQR(SUM(R,YLD(R,C)*XN(R,C)$XACRE(R,C))))

*** USE OF EACH WATER SOURCE CANNOT EXCEED AVAILABLE QUANTITY

 SOURCE(R,W)..  WAT(R,W) =L= BWATER(R,W)*(1-CVLOSS(R,W)+REUSE(R,W));

*** THIS EQUATION CALCULATES THE BASE PRICE. PRICE PREMIUMS AND DEFICIENCY
*** PAYMENTS ARE ADDED BY REGION.

PRICE(C).. P(C) =E= PBASE(C)*(1-FLEX(C))
 + FLEX(C)*(PBASE(C)/SUM( R,YLD(R,C)*XACRE(R,C)*(1+ON20*ADJ20(R,C)) ))
 * SUM(R,YLD(R,C)*XN(R,C)$XACRE(R,C)) ;


*** RESOURCE CONSTRAINTS ON WATER AND LAND. ASSUME CROPPED AREA CAN
*** INCREASE BY TEN PERCENT COMPARED TO CALIBRATION PERIOD

 RESOURCEW(R)..  SUM(C, WATAPP(R,C) * XN(R,C)$XACRE(R,C) )
                      =L= SUM(W,WAT(R,W));

 RESOURCEL(R)..  SUM(C, XN(R,C)$XACRE(R,C)) =L= 1.1*SUM(C, XACRE(R,C));

*** THE FOLLOWING CONSTRAINTS CALIBRATE THE ACRES BY CROP AND REGION,
*** NOT TECHNOLOGY.

 CALCROPU(R,C)$XACRE(R,C)..  XN(R,C) =L=  XACRE(R,C) *1.0000001;

 CALCROPL(R,C)$XACRE(R,C)..  XN(R,C) =G=  XACRE(R,C) *0.9999999;

*** ISOQUANT GOVERNING THE TRADEOFF BETWEEN APPLIED WATER AND IRRIGATION
*** TECH. FOR ELASTICITY EQUAL TO 1 THE CES REDUCES TO COBB  DOUGLAS CASE

 CESTECH1(R,C)$( XACRE(R,C) AND (SUB1(R,C) NE 1) )..
   A1(R,C)*( B1(R,C)*(WATAPP(R,C)/ETAW(R,C))**RHO(R,C)
     + (1-B1(R,C))*IRCST(R,C)**RHO(R,C) )**(1/RHO(R,C)) =E= 1;
 CESTECH2(R,C)$( XACRE(R,C) AND (SUB1(R,C) EQ 1) )..
   A1(R,C)*(WATAPP(R,C)/ETAW(R,C))**B1(R,C)*IRCST(R,C)**(1-B1(R,C)) =E= 1;
```

```
*** CALIBRATE WATER APPLICATION TO OBSERVED AW PER ACRE

 IRRAPP(R,C)$XACRE(R,C)..  WATAPP(R,C) =E= AW(R,C)
```

PMP MODEL

The PMP model is similar to the calibration model, except that it does not include the acreage and applied water calibration constraints, and it has a modified objective function.

The PMP objective function also represents the sum of producer and consumer surplus, except that net revenue for the PMP model includes the quadratic terms and a choice of four ways to calibrate both acres and water use. Option A uses an imputed irrigation system price, Option B uses an imputed water price, and Option C uses a cross product between water and acres to get irrigation efficiency and water use to calibrate. Option D uses the estimated substitution elasticities and the profit maximizing first-order conditions to adjust the estimated CES share and scale parameters. The final term in the objective function shown below is consumer surplus.

```
 PROFIT.. SUM((R,C), (YLD(R,C)*(P(C)+PREMIUM(R,C)+(.08+LR*.92)*DEFPMT(R,C))
    - HA2IA(R,C)*IRCST(R,C) - PCOST(R,C,'PHVAR') - LR*PCOST(R,C,'FIXED')
    - PCOST(R,C,'HVAR')*YLD(R,C) - ACOHD(R)) * XN(R,C)$XACRE(R,C))
    - SUM((R,W), (PWAT(R,W) + AFOHD(R,W)) * WAT(R,W))
    - SUM(R,WELLCOST*WAT(R,'GW'))
    - SUM(R,PUMPCOST*DRD(R)*.5*(WAT(R,'GW')/GWPB(R)-1)*WAT(R,'GW'))
    - SUM( (R,C), CONST(R,C) + ALPHA(R,C)*XN(R,C)$XACRE(R,C)
          + .5*GAMMA(R,C)*1/(1+ON20*ADJ20(R,C))*SQR(XN(R,C)$XACRE(R,C)) )
*** OPTION A USES THE FOLLOWING LINE
*   - SUM( (R,C), (CWI(R,C,'IMPITPR')-1) * HA2IA(R,C)*IRCST(R,C)*XACRE(R,C))
*** OPTION B USES THE FOLLOWING LINE
*   - SUM( (R,C), CWI(R,C,'CWDIFF') * WATAPP(R,C) * XACRE(R,C) )
*** OPTION C USES THE FOLLOWING TWO LINES
*    - SUM( (R,C), CWI(R,C,'CWDIFF') * WATAPP(R,C) * XN(R,C)$XACRE(R,C) )
*    - SUM( (R,C), - CWI(R,C,'CWDIFF') * AW(R,C) * XN(R,C)$XACRE(R,C) )

 + SUM(C,
     -.5*FLEX(C)*PBASE(C)/SUM(R,YLD(R,C)*XACRE(R,C)*(1+ON20*ADJ20(R,C)))
                 * SQR(SUM(R,YLD(R,C)*XN(R,C)$XACRE(R,C))))

           =E= BASEPROF;

*** USE OF EACH WATER SOURCE CANNOT EXCEED AVAILABLE QUANTITY

 SOURCE(R,W)..  WAT(R,W) =L= BWATER(R,W)*(1-CVLOSS(R,W)+REUSE(R,W));

*** THIS EQUATION CALCULATES THE BASE PRICE. PRICE PREMIUMS AND DEFICIENCY
*** PAYMENTS ARE ADDED BY REGION.

PRICE(C).. P(C) =E= PBASE(C)*(1-FLEX(C))
 + FLEX(C)*(PBASE(C)/SUM( R,YLD(R,C)*XACRE(R,C)*(1+ON20*ADJ20(R,C)) ))
 * SUM(R,YLD(R,C)*XN(R,C)$XACRE(R,C)) ;

*** RESOURCE CONSTRAINTS ON WATER AND LAND. ASSUME CROPPED AREA CAN
*** INCREASE BY TEN PERCENT COMPARED TO CALIBRATION PERIOD

 RESOURCEW(R)..  SUM(C, WATAPP(R,C) * XN(R,C)$XACRE(R,C) )
                           =L= SUM(W,WAT(R,W));

 RESOURCEL(R)..  SUM(C, XN(R,C)$XACRE(R,C)) =L= 1.1*SUM(C, XACRE(R,C));
```

```
*** ISOQUANT GOVERNING THE TRADEOFF BETWEEN APPLIED WATER AND IRRIGATION
*** TECH. FOR ELASTICITY EQUAL TO 1 THE CES REDUCES TO COBB DOUGLAS CASE

 CESTECH1(R,C)$( XACRE(R,C) AND (SUB1(R,C) NE 1) )..
          A1(R,C)*( B1(R,C)*(WATAPP(R,C)/ETAW(R,C))**RHO(R,C)
            +(1-B1(R,C))*IRCST(R,C)**RHO(R,C)  )**(1/RHO(R,C)) =E= 1;

 CESTECH2(R,C)$( XACRE(R,C) AND (SUB1(R,C) EQ 1) )..
    A1(R,C)*(WATAPP(R,C)/ETAW(R,C))**B1(R,C)*IRCST(R,C)**(1-B1(R,C)) =E= 1
```

POLICY CHANGE AND OUTPUT MODULE

The Policy Change and Output Module is one in which the analyst tells the model to evaluate the impacts of some change in resource or market conditions. An example could be a valley-wide or a region-specific reduction in surface water delivered by one of the water projects. Other examples could include: imposing a requirement that a given region achieve a target on-farm irrigation efficiency; increasing the price of surface water; or increasing the pumping lift and cost of groundwater.

The analyst is required to write some code in the GAMS language in order to impose a policy change and create output tables. The code could be simple or complex, and should be written by someone familiar with GAMS and with the structure and mechanics of the CVPM.

CENTRAL VALLEY PROJECT IMPROVEMENT ACT
PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT

DRAFT METHODOLOGY/MODELING TECHNICAL APPENDIX

CVPTM M/M

September 1997

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

af	acre-feet
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CVPM	Central Valley Production Model
CVPTM	Central Valley Production and Transfer Model
DWR	California Department of Water Resources
ET	evapotranspiration
M&I	municipal and industrial
O&M	Operation and Maintenance
OM&R	Operation, Maintenance, and Replacement
PEIS	Programmatic Environmental Impact Statement
PROSIM	Project Simulation Model
Reclamation	U.S. Bureau of Reclamation
SANJASM	San Joaquin Area Simulation Model
SWP	State Water Project
taf	thousand acre-feet
TB	Transfer Base Rate
TS	Transfer Service Rate

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CHAPTER I

INTRODUCTION

Chapter I

INTRODUCTION

Water transfers play several different, but related, roles within the Central Valley Project Improvement Act (CVPIA). Most importantly, expanding the use of voluntary water transfers is identified as one of the purposes of CVPIA [section 3402(d)]. Specifically, section 3405(a) states that individuals or districts receiving CVP water may transfer all or a portion of that water to any other California water user or water agency for any purpose recognized as beneficial under state law. Various provisions of CVPIA place restrictions, conditions, and costs on the transfer of CVP water. Water purchases are also a major vehicle by which the water acquisition program can obtain additional supplies of water for fish and wildlife purposes, as described in Section 3406(b)(3).

The water transfer analysis is designed to assess the programmatic impacts that transfers might have on municipal water supply costs, agricultural economics, and costs of the water acquisition program. The purposes of the water transfer analysis are to:

- identify opportunities for water transfers and show how these opportunities change under different PEIS alternatives;

- indicate potential buying and selling regions and estimate relative price ranges for water sales in different regions;

- estimate potential change in water use, the amount of land fallowing, and the change in agricultural net revenue resulting from transfers; and

- estimate costs of water acquired for fish and wildlife purposes under conditions of competition with other potential water buyers.

The analysis is based primarily on results and implications of the Central Valley Production and Transfer Model (CVPTM). CVPTM is a regional, planning model to evaluate CVPIA provisions and conduct other sensitivity and policy analysis. It is not used to estimate physical capacity to move water or to identify exactly who will be affected. It is not meant to be used to define which agencies will transfer water either as buyers or sellers. Many of the impacts potentially resulting from a water transfer are specific to the proposed transfer, and can only be described generally within a programmatic analysis. Local transfers (e.g., between adjacent water users or within a water district) and localized impacts of transfers are not part of CVPTM.

The assumptions used in CVPTM are designed to provide a programmatic assessment of the impacts of CVPIA on interregional water transfers. Many of the potential environmental impacts of a particular water transfer, including localized groundwater and other potential third party effects, will be unique to the situation and must be addressed within project-specific environmental review.

CHAPTER II

DESCRIPTION

Chapter II

DESCRIPTION OF THE METHODOLOGY/MODEL

INTRODUCTION

This chapter first describes the relationship between the Central Valley Production and Transfer Model (CVPTM) and other economic and hydrologic models, followed by the discussion of CVPTM structure. Water transfer costs are discussed next. Finally, results of a model confirmation run to simulate the 1991 California Drought Water Bank is described.

MODEL LINKAGES

The CVPTM is linked with several other aspects of the impact analysis, including agricultural economic analysis, municipal and industrial (M&I) economic analysis, hydrologic simulation, and water acquisition for fish and wildlife. Figure II-1 shows the interactions between CVPTM and the Central Valley Production Model (CVPM), the M&I Water Cost Analysis, the Project Simulation Model (PROSIM), and the Water Acquisition Program. CVPM, M&I Water Cost, PROSIM, and the Water Acquisition Program are described in their respective M/M Technical Appendices.

CVPTM is an augmented version of CVPM that allows water transfers among regions. CVPM is a multi-regional model of irrigated agricultural production and economics that simulates the decisions of agricultural producers in the Central Valley of California. The model includes 22 crop production regions and up to 26 categories of crops. Without water transfers, CVPM estimates an implicit value of water by region which is the marginal increase in agricultural net revenues from an additional unit of water supply. CVPTM uses these implicit water values to describe a supply function for transferred water. It includes 11 agricultural regions (aggregated from the 22 regions), which are either potential buyers or sellers, and 10 M&I regions that are potential buyers. Figure II-2 shows the 11 Central Valley agricultural regions. Descriptions of crop production regions and aggregated crop categories are provided in Table II-1 and Table II-2, respectively.

STRUCTURE OF CVPTM

This section describes the main components of CVPTM. They include the CVPTM objective function, water transfer balance equations, M&I water transfer demand equations, water transfer feasibility matrix, water transfer conveyance loss matrix, and physical and institutional constraints. This section also discusses the options to model water acquisitions for fish and wildlife. Additional details on the mathematical specification of CVPTM are presented in Attachment A.

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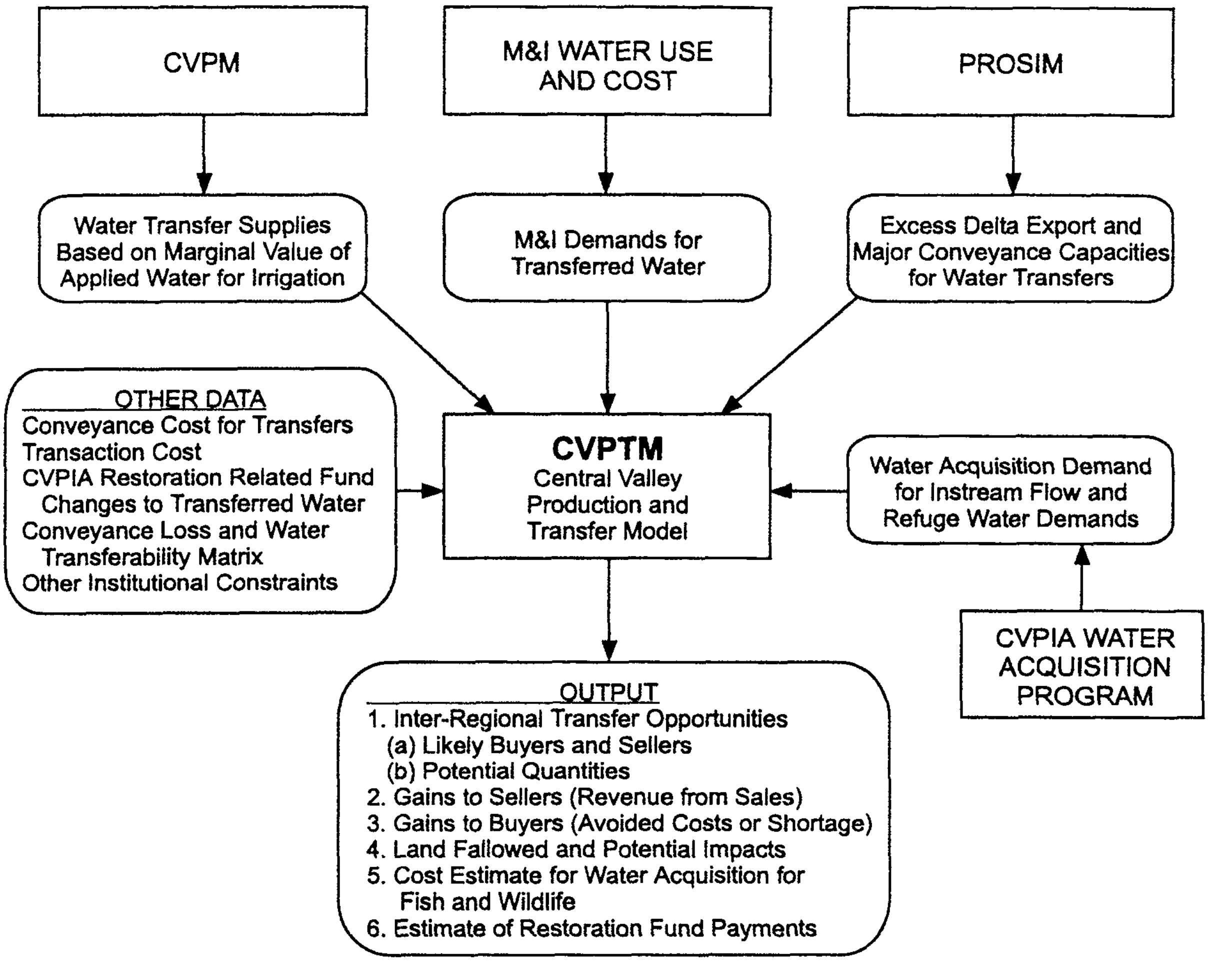

FIGURE II-1

CVPTM INTERACTION WITH CVPM, M&I ECONOMICS, PROSIM, AND WATER ACQUISITION PROGRAM

FIGURE II-2

AGRICULTURAL REGIONS

TABLE II-1

AGGREGATED CVPM CROP PRODUCTION REGIONS

Aggregated CVPTM Region	CVPM Region	Description of Major Water Users
Region 1	1	CVP Users: Anderson Cottonwood, Clear Creek, Bella Vista, some Sacramento River miscellaneous users.
	2	CVP Users: Corning Canal, Kirkwood, Tehama, some Sacramento River miscellaneous users.
Region 2	3	CVP Users: Glenn Colusa ID, Provident, Princeton-Codora, Maxwell, and Colusa Basin Drain MWC.
	3b	Tehama Colusa Canal Service Area. CVP Users: Orland-Artois WD, most of County of Colusa, Davis, Dunnigan, Glide, Kanawha, La Grande, Westside WD.
	4	CVP Users: Princeton-Codora-Glenn, Colusa Irrigation Co., Meridian Farm WC, Pelger Mutual WC, Rec. Dist, 1004, Rec. Dis. 108, Roberts Ditch, Sartain MWD, Sutter MWC, Swinford Tract IC, Tisdale Irrigation, some Sac River miscellaneous users.
Region 3	5	Most Feather River Region riparian and appropriative users.
	7	Sacramento Co. north of American River. CVP Users: Natomas Central MWC, some Sac River miscellaneous users, Pleasant Grove-Verona, San Juan Suburban.
Region 4	6	Yolo, Solano Counties. CVP Users: Conaway Ranch, other SAC River Miscellaneous users.
	9	Delta Regions. CVP Users: Banta Carbona, West Side, Plainview.
Region 5	8	Sacramento Co. south of American River, San Joaquin Co.
Region 6	10	Delta Mendota Canal. CVP Users: Panoche, Pacheco, Del Puerto, Hospital, Sunflower, West Stanislaus, Mustang, Orestimba, Patterson, Foothill, San Luis WD, Broadveiw, Eagle Field, Mercy Springs, Pool Exchange Contractors, Schedule II water rights, more.
Region 7	11	Stanislaus River water rights. Modesto ID, Oakdale ID, South San Joaquin ID.
	12	Turlock ID.
Region 8	13	Merced ID. CVP Users: Madera, Chowchilla, Gravely Ford.
Region 9	14	CVP Users: Westlands WD.
Region 10	15	Tulare Lake Bed. CVP Users: Fresno Slough, James, Tranquillity, Traction Ranch, Laguna, Rec. Dis. 1606.
	16	Eastern Fresno Co. CVP Users: Friant-Kern Canal, Fresno ID, Garfield, International.
	17	CVP Users: Friant-Kern Canal, Hills Valley, Tri-Valley Orange Cove.
	18	CVP Users: Friant-Kern Canal, County of Fresno, Lower Tule River ID, Pixley ID, portion of Rag Gulch, Ducor, County of Tulare, most of Delano Earlimart, Exeter, Ivanhoe, Lewis Cr., Lindmore, Lindsay-Strathmore, Porterville, Sausalito, Stone Corral, Tea Pot Dome, Terra Bella, Tulare.
Region 11	19	Kern Co. SWP Service Area.
	20	CVP Users: Friant-Kern Canal, Shafter-Wasco, S. San Joaquin.
	21	CVP Users: Cross Valley Canal, Friant-Kern Canal, Arvin Edison.

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TABLE II-2

AGGREGATED CVPTM CROP CATEGORIES

Aggregated Crop Category	Major Crops Included
1. Pasture	Pasture
2. Alfalfa	Alfalfa Hay
3. Sugarbeets	Sugarbeets
4. Rice	Rice
5. Cotton	Cotton
6. Grain	Wheat, barley, miscellaneous grain, miscellaneous hay
7. Field	Field corn, dry beans, oil seed, alfalfa seed, miscellaneous field crops
8. Truck	Melons, onions, potatoes, miscellaneous vegetables
9. Tomato	Fresh tomatoes, processing tomatoes
10. Orchard	Almonds, pistachios, peaches, prunes, walnuts, miscellaneous deciduous
11. Grapes	Raisins, wine grapes, table grapes
12. Subtropical	Citrus, olives, other subtropical

CVPTM OBJECTIVE FUNCTION

The CVPTM objective function extends the CVPM objective function (which maximizes agricultural net revenue and consumer surplus) by including water transfer costs and benefits, which are:

- Total conveyance costs for transfers between agricultural regions
- Seller's net revenue received from water sold
- Buyer's gains from water bought

Seller's net revenue received from water sold equals the gross revenue received minus water transfer cost, which will be discussed later. Buyer's gains are defined as consumer surplus for M&I buyers and as the increased profit made from crop production for agricultural buyers.

CVPTM solves for the price of the transferred water, crop mix, amount of irrigated land, and level of water transfers that maximize the sum of net revenue and consumer surplus for both agricultural production and water transfers.

WATER TRANSFER BALANCE EQUATIONS

The water balance equation for each selling region in CVPTM states that water used for crop production plus gross transfer out of the region must be less than or equal to water sources available plus net transfer into the region. The net transfer is measured at the destination. It equals the gross transfer measured at the selling region minus transfer conveyance losses and Delta outflow requirements for cross-Delta transfers. The conveyance losses and Delta outflow requirements are discussed later. Separate accounting is made for different sources of transferred water, including CVP water service contract, CVP water rights contracts, State Water Project (SWP), local surface water, and groundwater.

M&I WATER TRANSFER DEMAND EQUATIONS

CVPTM includes water transfer demand functions for 10 groups of M&I providers who may participate in Central Valley water markets. Table II-3 describes the major water users in the 10 M&I regions and Figure II-3 shows their geographic locations. The demand functions were developed based on water shortage estimates, capacity limitations, costs of alternative supplies, and costs of shortages. The price and quantity used in M&I demand functions represent untreated water (measured at the M&I buyer's treatment plant). Hence, the price of M&I water purchased includes the seller's price plus transfer conveyance costs and other water transfer related costs; the quantity is the net water received. For detailed information on the estimation of M&I transfer demand functions, refer to Municipal and Industrial Water Costs M/M Technical Appendix.

TABLE II-3

M&I WATER TRANSFER DEMAND REGIONS

CVPTM M&I Regions	Descriptions of Major Water Users
D1	Sacramento Area
D2	Shasta and Redding Area
D3	North Bay Aqueduct, Solano and Napa Counties
D4	CCWD
D5	San Felipe Division
D6	South Bay Aqueduct
D7	Central Coast
D8	Central Valley Cities
D9	KCWA and Bakersfield
D10	Southern California

WATER ACQUISITION FOR FISH AND WILDLIFE

There are two options in modeling water acquisition for fish and wildlife restoration. One is to include a set of demand functions for instream fish flow requirements and refuge water needs. These demand functions can be treated just like M&I demand functions such that the demands can be met either by local sources or by water transfers from other locations. In this option, CVPTM could group various fish and wildlife management areas into several demand regions based on similarity of geographical location and potential supply sources within the Central Valley.

The second option is to treat instream flows and refuge demands as physical constraints on water available to other users in regions in which the streams or refuge sites are located. In other words, these demands are assumed to be met during the hydrologic simulations, reducing water available for other users, so no specific demand functions need to be included in CVPTM. In the second option, average unit cost estimates for acquired water would be based on the water transfer results for a given alternative so that price effects due to competition from M&I and other water buyers would be included. The second option was used for incorporating the quantity and cost of acquired water for PEIS alternatives, and is discussed in Chapter III.

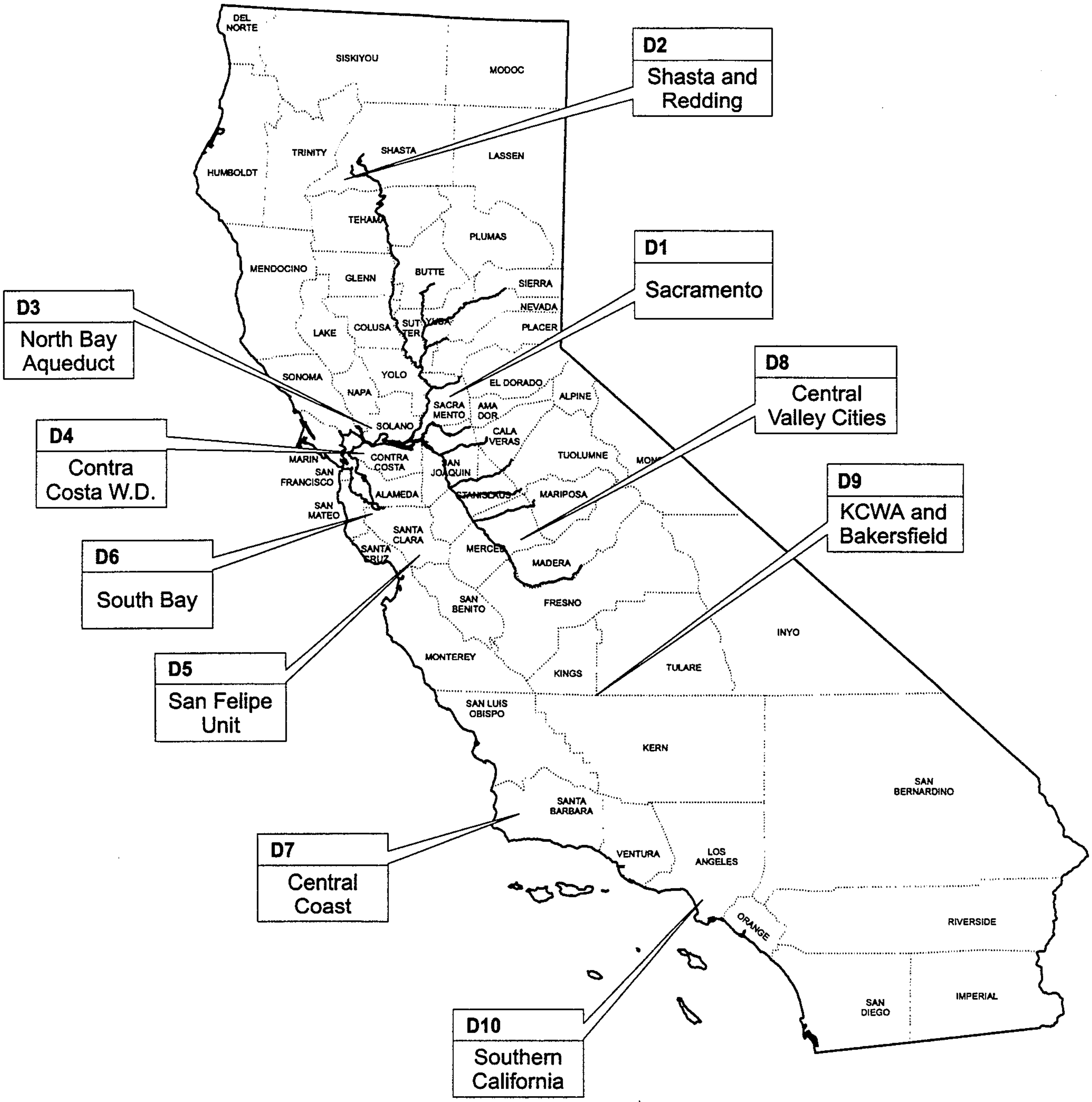

FIGURE II-3
URBAN DEMAND REGIONS

WATER TRANSFER FEASIBILITY MATRIX

The feasibility of regional water transfers in CVPTM is represented by a matrix of 22 possible origins (sellers) by 40 possible destinations (buyers). The destinations are 22 agricultural CVPM regions, 10 M&I users, and 8 wildlife refuges; the origins are 22 agricultural CVPM regions. Hence, agricultural regions can be buyers or sellers, but M&I users and refuges are water buyers only. As mentioned earlier, the 22 CVPM agricultural regions were aggregated into 11 regions for CVPTM, but the data for all 22 regions is presented.

Table II-4 shows the water transfer feasibility matrix. Each element in the matrix is either one or zero, where one represents a feasible water transfer or exchange. If there is no possible conveyance given current facilities, and no reasonable exchange opportunity exists, then the transfer is considered not feasible.

The CVPTM feasibility matrix allows two types of transfers: direct and exchange. In a direct transfer, water that would have been used by the seller is instead moved to the buyer. There are only two parties to the transfer. In an exchange transfer, there are at least three parties to the transfer, and the buyer does not usually obtain the seller's water. For example, in an exchange, the seller provides water to a willing third party, and the buyer receives water from another source that would have gone to the third party. For example, Kern County receives water from both the Friant-Kern Canal and the California Aqueduct, so a number of entities within Kern County could act as third parties in an exchange transfer between the service areas of those two canals.

Instream flow requirements that occur downstream of a potential seller could act as the third party in an exchange. This type of transfer may become important when multiple parties have obligations to meet Bay-Delta flow requirements. Water buyers could pay to have others assume their Bay-Delta requirements, and water sellers could offer their water to be used for meeting the buyers' requirements. For example, the U.S. Bureau of Reclamation (Reclamation) is currently obligated under the 1994 Bay-Delta Plan Accord to meet standards at Vernalis, and operates New Melones Dam on the Stanislaus River to do that. The Vernalis standards could also be physically met with Merced and Tuolumne River water, although water rights holders along these rivers are not currently required to help meet the standards. This provides some opportunity for exchange among users in those river basins.

Water from Eastside San Joaquin rivers can be released into the Delta and exported into the west San Joaquin Valley or south without any exchange. For example, Westlands Water District recently conducted such a transfer with Merced Irrigation District (California Department of Water Resources [DWR], 1994).

The information used to develop the matrix included (1) historical transfers or other movement of water that has occurred; (2) an obvious ability to accomplish an exchange, even if the exchange has never occurred; and (3) other considerations that might limit transfers in the 2020 condition. The transfer feasibility matrix allows transfers between most origins and destinations, because there are possible conveyance facilities or potential exchanges among most regions.

TABLE II- 4

WATER TRANSFERS: TRANSFER FEASIBILITY MATRIX

TO	FROM	R1 Redding Area	R2 CorningCanal	R3 GCID	R3B TC Canal	R4 Colusa Irri. Co.	R5 Feather River	R6 Yolo & Solano	R7 Sac. Co.	R8 East Delta	R9 Delta Region	R10 DMC	R11 Stan. River	R12 Turlock I.D.	R13 Merced I.D.	R14 Westl. W.D.	R15 Mid-V Area	R16 Fresno Area	R17 Kings River	R18 Ka,Tu. River	R19 West Kern	R20 East Kern	R21 Kern River
R1	Redding Area	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0	0	1	0	1
R2	Corning Canal	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0	0	1	0	1
R3	GCID	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0	0	1	0	1
R3B	TC Canal	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0	0	1	0	1
R4	Colusa Irri. Co.	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0	0	1	0	1
R5	Feather River	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0	0	1	0	1
R6	Yolo & Solano	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0	0	1	0	1
R7	Sac.County	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0	0	1	0	1
R8	East Delta	0	0	0	0	0	0	0	1	1	1	0	1	0	0	0	0	0	0	0	0	0	0
R9	Delta Region	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
R10	DMC	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
R11	Stan. River	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0
R12	Turlock ID	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
R13	Merced ID	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	1	1
R14	Westl. WD	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1
R15	Mid- V Area	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
R16	Fresno Area	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1
R17	Kings River	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1
R18	Ka,Tu. River	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1
R19	West Kern	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1
R20	East Kern	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1
R21	Kern River	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D1	Sac. Area	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0	0	1	0	1
D2	Shasta Area	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	0	0	0	0	0
D3	NBA	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0	0	1	0	1
D4	CCWD	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	0	0	1	0	1
D5	San Felipe	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	0	0	1	0	1
D6	SBA	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	0	0	1	0	1
D7	Coast Branch	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	0	0	0	1	0	1
D8	CV Cities	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	1
D9	KCWA	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
D10	South Coast	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	1
REF1	Sac. Ref	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	0	0	0	0	0
REF2	Gray Lodge	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	0	0	0	0	0
REF3	Sutter NWR	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	0	0	0	0	0
REF4	SJ Valley	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	1
REF5	Merced NWR	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	0	1	1
REF6	Mendota WMA	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	1
REF7	Pixley WMA	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	1	1
REF8	Kern NWR	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0	0	1	1	1

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TRANSFER CONVEYANCE LOSS MATRIX

Table II-5 presents the CVPTM transfer loss matrix. Like the water transfer feasibility matrix, the transfer loss matrix also has 22 possible origins (sellers) and 40 possible destinations (buyers). The coefficients in the loss matrix represent percentage of seller's water received at the buyer's location. For example, the coefficient 0.57 between Region 1 (seller in Redding area) and Region 14 (buyer in Westlands Water District) implies that to receive 57 acre-feet water at Westlands one needs to purchase 100 acre-feet from a seller in the Redding area; the difference of 43 acre-feet represents a transfer loss. The relationship between the loss coefficients from point A to B to C vs. from point C to B to A can be shown as follows. Assume the percentage losses are a, b, and c, respectively, then 100 acre-feet would become a*b*c*100 from A to C and a*b*c*100 would become (1/a*1/b*1/c)*(a*b*c*100) from C to A. CVPTM transfer conveyances loss consists of two sources, Delta outflow requirements for cross-Delta transfers and other conveyance losses.

DELTA OUTFLOW REQUIREMENTS

The 1994 Bay-Delta Plan Accord imposes the following restrictions on exports as a percent of delta inflow:

- In February, exports can be up to 35 and 45 percent of delta inflow when the Eight River Index is greater than 1.5 million acre-feet and less than 1 million acre-feet respectively, with administrative discretion in the middle range.
- In March through June, exports can be no greater than 35 percent of Delta inflow.
- In July through January, exports can be no greater than 65 percent of Delta inflow.

Based on these principles, CVPTM assumes that buyers and sellers would attempt to transfer water across the Delta during the July through January period only, if capacity is available. Therefore, the Delta requirement would be estimated at 35 percent of delta inflow. For example, if a seller wishes to provide 65 acre-feet water from lower Sacramento River Region for export south of the Delta, 100 acre-feet must be provided as inflow to the Delta.

CONVEYANCE LOSSES FROM STREAMS AND CANALS

CVPTM assumes that up to 5 percent of water made available from an origin in the Sacramento River Region can be lost en route to the Delta, and an additional 5 percent can be lost en route to southern California. Hence, the total potential loss from Sacramento River Region to southern California is 10 percent. A 10 percent loss is also assumed for San Joaquin River Region water transferred through the south Delta to the export pumps. These estimates were used for the PEIS analysis, but are easily changed if better estimates are available.

TABLE II-5

WATER TRANSFERS: DISTRIBUTION LOSS MATRIX

TO	FROM	R1 Redding Area	R2 Corning Canal	R3 GCID	R3B TC Canal	R4 Colusa Irri. Co.	R5 Feather River	R6 Yolo & Solano	R7 Sac. County	R8 East Delta	R9 Delta Region	R10 DMC	R11 Stan. River	R12 Turlock ID	R13 Merced ID	R14 Westl. WD	R15 Mid-V Area	R16 Fresno Area	R17 Kings River	R18 Ka,Tu. River	R19 West Kern	R20 East Kern	R21 Kern River
R1	Redding Area	1.00	1.00	1.00	1.00	1.02	1.03	1.03	1.04	1.05	1.25	1.67	1.67	1.72	1.72	1.75	1.75	1.79	1.79	1.82	1.82	1.82	1.82
R2	Corning Canal	1.00	1.00	1.00	1.00	1.02	1.03	1.03	1.04	1.05	1.25	1.67	1.67	1.72	1.72	1.75	1.75	1.79	1.79	1.82	1.82	1.82	1.82
R3	GCID	1.00	1.00	1.00	1.00	1.02	1.03	1.03	1.04	1.05	1.25	1.67	1.67	1.72	1.72	1.75	1.75	1.79	1.79	1.82	1.82	1.82	1.82
R3B	TC Canal	1.00	1.00	1.00	1.00	1.02	1.03	1.03	1.04	1.05	1.25	1.67	1.67	1.72	1.72	1.75	1.75	1.79	1.79	1.82	1.82	1.82	1.82
R4	Colusa Irri. Co.	0.98	0.98	0.98	0.98	1.00	1.00	1.02	1.03	1.04	1.23	1.64	1.64	1.69	1.69	1.72	1.72	1.75	1.75	1.79	1.79	1.79	1.79
R5	Feather River	0.97	0.97	0.97	0.97	1.00	1.00	1.01	1.02	1.03	1.22	1.61	1.61	1.67	1.67	1.69	1.69	1.72	1.72	1.75	1.75	1.75	1.75
R6	Yolo & Solano	0.97	0.97	0.97	0.97	0.98	0.99	1.00	1.02	1.03	1.22	1.61	1.61	1.67	1.67	1.69	1.69	1.72	1.72	1.75	1.75	1.75	1.75
R7	Sac. County	0.96	0.96	0.96	0.96	0.97	0.98	0.98	1.00	1.02	1.20	1.59	1.59	1.64	1.64	1.67	1.67	1.69	1.69	1.72	1.72	1.72	1.72
R8	East Delta	0.95	0.95	0.95	0.95	0.96	0.97	0.97	0.98	1.00	1.19	1.56	1.56	1.61	1.61	1.64	1.64	1.67	1.67	1.69	1.69	1.69	1.69
R9	Delta Region	0.80	0.80	0.80	0.80	0.81	0.82	0.82	0.83	0.84	1.00	1.45	1.45	1.49	1.49	1.52	1.52	1.54	1.54	1.56	1.56	1.56	1.56
R10	DMC	0.60	0.60	0.60	0.60	0.61	0.62	0.62	0.63	0.64	0.69	1.00	1.01	1.03	1.03	1.04	1.04	1.05	1.05	1.06	1.06	1.06	1.06
R11	Stan. River	0.60	0.60	0.60	0.60	0.61	0.62	0.62	0.63	0.64	0.69	0.99	1.00	1.01	1.01	1.02	1.02	1.03	1.03	1.04	1.04	1.04	1.04
R12	Turlock ID	0.58	0.58	0.58	0.58	0.59	0.60	0.60	0.61	0.62	0.67	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
R13	Merced ID	0.58	0.58	0.58	0.58	0.59	0.60	0.60	0.61	0.62	0.67	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
R14	Westl. WD	0.57	0.57	0.57	0.57	0.58	0.59	0.59	0.60	0.61	0.66	0.96	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
R15	Mid- V Area	0.57	0.57	0.57	0.57	0.58	0.59	0.59	0.60	0.61	0.66	0.96	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
R16	Fresno Area	0.56	0.56	0.56	0.56	0.57	0.58	0.58	0.59	0.60	0.65	0.95	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
R17	Kings River	0.56	0.56	0.56	0.56	0.57	0.58	0.58	0.59	0.60	0.65	0.95	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
R18	Ka,Tu. River	0.55	0.55	0.55	0.55	0.56	0.57	0.57	0.58	0.59	0.64	0.94	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
R19	West Kern	0.55	0.55	0.55	0.55	0.56	0.57	0.57	0.58	0.59	0.64	0.94	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
R20	East Kern	0.55	0.55	0.55	0.55	0.56	0.57	0.57	0.58	0.59	0.64	0.94	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
R21	Kern River	0.55	0.55	0.55	0.55	0.56	0.57	0.57	0.58	0.59	0.64	0.94	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
D1	Sac. Area	0.97	0.97	0.97	0.97	0.98	1.00	1.00	1.00	1.00	1.33	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66
D2	Shasta Area	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.33	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66	1.66
D3	NBA	0.80	0.80	0.80	0.80	0.81	0.82	0.82	0.83	0.84	1.00	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
D4	CCWD	0.60	0.60	0.60	0.60	0.61	0.62	0.62	0.63	0.64	0.69	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
D5	San Felipe	0.58	0.58	0.58	0.58	0.59	0.60	0.60	0.61	0.62	0.67	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
D6	SBA	0.60	0.60	0.60	0.60	0.61	0.62	0.62	0.63	0.64	0.69	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99
D7		0.55	0.55	0.55	0.55	0.56	0.57	0.57	0.58	0.59	0.64	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
D8	CV Cities	0.58	0.58	0.58	0.58	0.59	0.60	0.60	0.61	0.62	0.67	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97

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TABLE II-5. CONTINUED

TO	FROM	R1 Redding Area	R2 Coming Canal	R3 GCID	R3B TC Canal	R4 Colusa Irri. Co.	R5 Feather River	R6 Yolo & Solano	R7 Sac. County	R8 East Delta	R9 Delta Region	R10 DMC	R11 Stan. River	R12 Turlock ID	R13 Merced ID	R14 Westl. WD	R15 Mid-V Area	R16 Fresno Area	R17 Kings River	R18 Ka,Tu. River	R19 West Kern	R20 East Kern	R21 Kern River
D9	KCWA	0.58	0.58	0.58	0.58	0.59	0.60	0.60	0.61	0.62	0.67	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
D10	South Coast	0.55	0.55	0.55	0.55	0.56	0.57	0.57	0.58	0.59	0.64	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
REF1	Sac. Ref	1.00	1.00	1.00	1.00	1.02	1.03	1.03	1.04	1.05	1.11	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
REF2	Gray Lodge	0.97	0.97	0.97	0.97	1.00	1.00	1.01	1.02	1.03	1.09	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
REF3	Sutter NWR	0.97	0.97	0.97	0.97	1.00	1.00	1.01	1.02	1.03	1.09	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
REF4	SJ Valley	0.80	0.80	0.80	0.80	0.81	0.82	0.82	0.83	0.84	0.89	1.00	1.01	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
REF5	Merced NWR	0.78	0.78	0.78	0.78	0.79	0.80	0.80	0.81	0.82	0.87	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
REF6	Mendota WMA	0.80	0.80	0.80	0.80	0.81	0.82	0.82	0.83	0.84	0.89	1.00	1.01	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
REF7	Pixley WMA	0.75	0.75	0.75	0.75	0.76	0.77	0.77	0.78	0.79	0.84	0.94	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
REF8	Kern NWR	0.75	0.75	0.75	0.75	0.76	0.77	0.77	0.78	0.79	0.84	0.94	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

NOTE:
The name of region given in this table is not a complete definition. It only shows a common area name for identification purposes.

DELTA EXPORT AND MAJOR CONVEYANCE CAPACITIES AVAILABLE FOR WATER TRANSFERS

CVPTM obtains information on excess Delta export and major conveyance capacities available for water transfers from PROSIM. These capacities vary by PEIS alternative. Detailed analysis is in the Water Facilities and Supplies Technical Appendix. Summary information used for water transfer analysis of the PEIS alternatives is provided in Chapter III.

OTHER CONSTRAINTS

Other constraints included in CVPTM for analysis of PEIS alternatives are listed below. Additional explanation of the assumptions used to impose these constraints is found in the Water Transfer Opportunities Technical Appendix.

- Only evapotranspiration (ET) of applied water or other irrecoverable losses may be transferred. The share of applied water that may be transferred varies by crop and by region according to estimates of applied water and ET per acre for each crop.
- An upper bound is placed on transfers out of a region to limit the third party impacts.
- No transfer of groundwater or substitution of groundwater for transferred surface water is allowed. This assumption is tested by several sensitivity runs allowing groundwater substitution.
- Savings from irrigation improvements that do not result in a reduction of ET or irrecoverable loss are not transferable, to assure that "real water" is being transferred.
- Because of limitations on the transferability of water diverted under riparian rights, CVPTM assumes this water is not transferable for agricultural or M&I uses. The aggregate, regional structure of the modeling means that this only becomes a constraint on transfers out of the Delta region.

WATER TRANSFER COSTS

This section describes the water transfer costs used in CVPTM. First, definitions and general rules are discussed, followed by the description of specific transfer costs for water sources. Some illustration values for transfer costs are also presented next. **All of the costs described below represent estimates or preliminary calculations based on the best information available at the time the analysis was being developed. These estimates are believed to be adequate to provide a programmatic environmental assessment of water transfer impacts, but should not be viewed as a final determination of transfer charges by Reclamation.**

TRANSFERS BETWEEN CVP CONTRACTORS

Water transfer costs of CVP water are based on Reclamation's cost-of-service rate components. The cost of service rates and their components are taken from Reclamation's 1992 Irrigation Water Rates, Central Valley Project, California, and 1992 Municipal and Industrial Water Rates, Central Valley Project, California.

CVPTM water transfer rates for CVP water follow Reclamation's rule for short-term transfers. More specifically, the rules are as follows:

- The transfer must bear the cost of the higher of the capital rates, as well as the unavoidable O&M costs, based on the rates applicable to the seller's location and the buyer's location.

- The transfer need not bear the cost of avoidable energy costs, where energy is no longer used after the transfer. Reciprocally, in transferring water to a new location, the transfer would bear the cost of any additional energy costs.

For purposes of explaining these concepts, two new terms (not used in Reclamation's publications on water rates) are defined below.

The Transfer Base Rate (TB) consists of the capital components of the CVP cost of service rates, plus the unavoidable (non-energy) O&M components such as water marketing, storage, and conveyance. Reclamation's transfer rules require that a buyer pay the larger of TB at the destination or the source.

The Transfer Service Rate (TS) consists of the avoidable energy costs, which are 50% of conveyance pumping and 85 percent of direct pumping.

More formally, let s indicate the source district; d indicate the destination district; TB equal the base transfer rate; and TS equal the transfer service rate. Then the original CVP cost of service rate payable at the source location as part of the cost of water is equal to:

$$\text{cost of service rate} = TB_s + TS_s$$

The CVP charge to be paid by the transfer is the additional amount that must be paid after the transfer (a difference which could be negative, but will often be positive):

$$\text{Max}(TB_d , TB_s) - TB_s + (TS_d - TS_s)$$

The first two terms of the formula yield any increase resulting from applying the maximum of the two transfer base rates. The second part, $(TS_d - TS_s)$, adjusts for any change in the amount of electrical energy used.

TRANSFERS BETWEEN SWP CONTRACTORS

Transfers to SWP contractors using the State Water Project do not require additional payments for capital. Rather, purchasers are required to pay only the increase in energy costs and the increase in variable Operation, Maintenance, and Replacement costs (variable OM&R). Let the sum of variable O&M and energy costs be TV, then for transferring water among two SWP contractors, the charge is:

$$TV_d - TV_S ,$$

which adjusts the transfer cost for any changes in variable O&M and energy.

TRANSFERS BETWEEN DIFFERENT CONTRACTORS

Letting TV equal zero for CVP contractors and non-project contractors and letting TB equal zero and TS equal zero for SWP contractors and non-project contractors, the formula for transfers among any two agricultural entities is:

$$\max(TB_d, TB_s) - TB_s + (TS_d - TS_s) + (TV_d - TV_S)$$

TRANSFERS SUBJECT TO CVPIA CHARGES

The CVPIA imposed a number of charges on CVP contractors and on transfers which can affect water transfer costs. The following paragraphs introduce these charges and describe how CVPTM incorporates them into its water transfer cost. All of the water transfer related CVPIA charges, as discussed below, will accrue to the CVPIA Restoration Fund. All charges are expressed in 1992 dollars, and most are indexed for inflation per CVPIA.

- Restoration fund charges, per CVPIA-Section 3407(d)(2)(A). A restoration fund charge of \$6 per acre-foot is assessed against all CVP irrigation contractors, excluding the base supply of Sacramento River contracts and San Joaquin River exchange contract delivery. For M&I entities, the Restoration Fund charge is \$12 per acre-foot for CVP project water. When water is transferred from irrigation use to M&I use, the Restoration Fund charge increases from \$6 to \$12 per acre-foot.

- Friant-Kern surcharge is set at \$7 per acre-foot, per CVPIA-Section 3406(c)(1). The Friant Division Surcharge is levied in lieu of water releases for the restoration of flows between Gravelly Ford and Mendota Pool, pending completion of the San Joaquin River Comprehensive Plan and necessary Congressional action. The surcharge follows a graduated schedule, beginning at \$4 per acre-foot until September 30, 1997, then increasing to \$5 per acre-foot until September 30, 1999, and \$7 per acre-foot thereafter. Because of uncertainties about the completion of the Comprehensive Plan and the ultimate recommendations for the plan, CVPTM uses \$7 per acre-foot for water transfer analysis in all PEIS alternatives.

  More specifically, the Friant-Kern surcharge is added to the transfer base rate in the above formulas. This accomplishes the purpose of adding the surcharges to any water transferred into the Friant-Kern unit (under the assumption that such a transfer or exchange would require the use of Friant-Kern facilities). If water is transferred out of the Friant-Kern unit, it retains the surcharge.

- Full-cost increment for transfers to non-CVP agricultural users, per CVPIA-Section 3405(a)(1)(b). If CVP agricultural water is transferred to a non-CVP agricultural user, then the rate must be raised to the full cost rate. Let FC equal the CVP full cost rate and CS equal the CVP cost of service rate; then the full cost increment at the sources (s) is:

$$FCs - CSs$$

- Transfer from agricultural to M&I contractors pays conversion cost, per CVPIA-Section 3405(a)(1)(b). An M&I entity using water at the same location would pay the increment in the transfer base rate and possibly some increment in the transfer service rate. The increment would depend upon the irrigation rates and the M&I rates at that location. Let TB equal the agricultural base transfer rate, TS equal the agricultural transfer service rate, MTB equal the M&I base transfer rate, and MTS equal the M&I transfer service rate. Then the incremental rate charged for conversion to M&I is:

$$\max(MTBs, TBs) - TBs + (MTSs - TSs)$$

- A $25 per acre-foot increment to non-CVP M&I users, per Section 3407(d)(2)(A). If CVP agricultural water is transferred to a non-CVP M&I user, then $25 per acre-foot is added to the transfer rates.

SPECIAL CASE OF SAN JOAQUIN RIVER EXCHANGE CONTRACTORS

The San Joaquin River exchange contractors are Central California I.D., Columbia Canal Co., Firebaugh Canal Co., and the San Luis Canal Co. These contractors lie within CVPTM aggregated regions 6 and 8.

The CVP exchange contractors represent something of a special case in that these contractors do not pay CVP cost of service rates for the use of water, but those rates (cost of service) must be paid to Reclamation if the water is transferred. Nor do the exchange contractors pay any of the CVPIA-related charges, such as the Restoration Fund charges. Furthermore, if the exchange contractors transfer water to another location, Restoration Fund charges are not assessed.

TRANSFERS TO WILDLIFE REFUGES

At the time of preparation of CVPTM, Reclamation had not yet adopted written policies on the transfer rates that would be applicable to refuges. The following rules and formulas were based on conversations with Reclamation personnel responsible for developing the guidelines on applying CVPIA charges to water districts.

In general, the refuges would be charged the transfer service rate, but would not be subject to paying any additional capital costs for existing CVP facilities. The cost of those facilities are already paid under allocations to existing project contractors. In other words, the greater-of rule for the base transfer rate does not apply for water transfers to fish and wildlife. Furthermore, Reclamation does not plan to assess Restoration Fund charges for water purchased for wildlife refuges.

ILLUSTRATIVE VALUES OF TRANSFER COSTS

To help the reader understand CVPTM water transfer costs, the following sections first summarize the rules used to develop the transfer cost formulas, as discussed above. Then, some examples of transfer costs between different contractors are presented.

SUMMARY OF CVPTM WATER TRANSFER COSTS

In general, a transfer to those parts of the CVP with higher capital costs than others would require an increased payment for capital (an increase in the Base Transfer rate). Such transfers might include, for example, those to an area using a conveyance canal from an area that does not use the canal, or a transfer that requires conveyance through the Delta-Mendota Canal from an area with lower capital costs. Transfers to areas with lower capital costs do not result in a reduction in capital costs because Reclamation's transfer rules require that the transfer bear the greater of the two transfer base rates. The energy costs (the transfer service rate) may also be higher for transfers that use additional pumping (e.g., transfers that require use of the Delta Mendota Canal from an area that used less pumping, or transfers into the San Felipe Division). If a water transfer results in less use of energy, then there is a credit for the unused energy.

Transfers to SWP contractors using the State Water Project do not require additional payments for capital. Rather, purchasers are required to pay only the increase in energy costs and the increase in variable Operation, Maintenance, and Replacement costs (variable OM&R). As a result, transfers to areas farther south in the SWP generally require additional charges. Reciprocally, if water were transferred from southern parts of the SWP to areas farther north, the transfer would receive a reduction in the charge for energy and variable OM&R.

In general, transfers to fish and wildlife uses as part of the water acquisition program would be charged the transfer service rate, but would not be subject to any additional capital costs for existing CVP facilities, nor to any CVPIA Restoration Fund charges.

EXAMPLES

Table II-6 shows some examples of how these rules are applied. The following paragraphs discuss these examples step by step.

From CVP Contractors in R1

The CVP water users in Region 1, at the northern part of the project, have a transfer base rate averaging $11.84 /acre-foot (the actual rates range from 7.94 to 13.51) and an average transfer service rate of 1.11 $/acre-foot (the actual rates range from 1.48 to 2.28).

TABLE II-6

SELECTED WATER TRANSFER RATES

Sellers		Agricultural Buyers R1	R11	R14	R21	M&I Buyers D5	D10	F&W Buyers Ref 8
R1	C	0.00		15.17	50.70	149.78	204.96	16.17
R11	N		0.00	34.12	26.90	168.72	155.56	23.28
R21	S	-7.95		-7.22	0.00	141.82	115.92	-16.36

NOTES:
R = Region, C = CVP water, S = SWP water, and N = Non-project water.
The shaded areas mean that water transfer is not feasible.
For the region definitions, refer to Tables II-1 through II-3.

To R14 (CVP buyer). The average transfer base rate in this region, which includes the Westlands Water District, is $25.51/acre-foot (with the actual values ranging from 17.04 to 30.22). The average transfer service rate is $2.61/acre-foot, reflecting pumping costs from the Delta (the actual rates range from 1.48 to 3.24).

Under the maximum-of rule for the transfer base rate, the transfer must bear an increase of $13.67/acre-foot (from 11.84 to 25.51). The transfer also bears an increase of $1.50/acre-foot (2.61 - 1.11) in the transfer service rate.

The transfer is between two CVP agricultural contractors, so no other CVPIA charges are assessed. Hence, the total of these two increases is $15.17/acre-foot = $13.67/acre-foot + $1.50/acre-foot.

To R21 (SWP buyer). Transfer charges are high because water is sold to a region much farther south and to a non-CVP buyer.

Since the transfer is to a SWP buyer, conveyance through SWP facilities is assumed. The energy and variable OM&R charged by the state would be $26.90/acre-foot. This amount is $25.79/acre-foot higher than the CVP transfer service Rate (1.11), which no longer has to be paid.

In addition, the transfer has to pay an amount of $24.91/acre-foot to increment the cost of service rate to full cost in R1.

The total of these two amounts (25.79 + 24.91) is $50.70/acre-foot.

To D5 (CVP buyer). This region, comprising districts in the San Felipe Division of the CVP, has capital costs much higher than the other portions of the CVP. This is the principal factor accounting for large rate increases for transfer to this region.

The transfer base rate in this region averages $150.65/acre-foot, considerably higher than the transfer base rate for M&I use in R1. Under the maximum-of rule, this increases the transfer base rate by $138.81/acre-foot (150.65 - 11.84).

The transfer service rate for D5 averages $6.07/acre-foot, due to higher pumping costs, representing an increase in the transfer service rate of $4.96/acre-foot (6.07 - 1.11).

Since the water is converted to M&I use, the Restoration Fund charge increases by $6 per acre-foot.

Totaling these amounts yields a rate increase of $149.77/acre-foot (138.81 + 4.96 + 6).

To D10 (SWP M&I buyer). D10 represents the SWP service area in Southern California. There will be a conversion cost from CVP to Non-CVP M&I of $25.52/acre-foot (43.36-17.84) and a $25/acre-foot surcharge for transferring CVP irrigation water to Non-CVP M&I users. The transfer will use SWP facilities with a cost of $155.56/acre-foot, but will save $1.11/acre-foot CVP transfer service. The total is $204.96 /acre-foot (25.52+25+155.56-1.11).

To REF8. REF8 is the Kern National Wildlife Refuge, served by the SWP through the Buena Vista Water District. A transfer from R1 would be made through SWP conveyance from the Delta.

The energy and variable OM&R charges of the SWP from the Delta to this point are $23.28/acre-foot.

The transfer would avoid $1.11/acre-foot in CVP energy costs. The transfer would also avoid the $6 Restoration Fund charge. None of the CVPIA charges is assessed against transfers for fish and wildlife purposes.

As a result, the change in project rates would be an increase of $16.17/acre-foot (23.28 - 1.11 - 6).

From Non-Project Sources in R11

To R14 (CVP buyer). This purchase is from a non-project source but will be wheeled through CVP facilities, so it pays the CVP cost-of-service for R14 plus the $6 Restoration Fund charge.

The total rate is $34.12/acre-foot (25.51 + 2.61 + 6).

To R21 (SWP buyer). Since the water is coming from a non-project source, the only charge is for wheeling through SWP facilities.

The sum of energy and variable OM&R costs for SWP contractors in R21 is $39.64/acre-foot.

To D5 (CVP buyer). This purchase is from a non-project source, but will be wheeled through CVP facilities. It pays the CVP cost-of-service rate for D5 plus the $12 Restoration Fund charge.

The total rate is $168.72/acre-foot (150.65 + 6.07 + 12).

To D10 (SWP buyer). Since the water is coming from a non-project source, the only charge is for wheeling through SWP facilities.

The sum of energy and variable OM&R costs for SWP contractors in D10 is $155.56/acre-foot.

To REF8. Since the water is coming from a non-project source, the only charge is for wheeling through SWP facilities.

The sum of energy and variable OM&R costs for REF 8 is 23.28 $/acre-foot

From SWP Contractors R21

To R1 (CVP buyer). This is a transfer from south of the Delta to north of the Delta, so SWP pumping would no longer be used. The transfer would avoid $26.90/acre-foot in SWP energy plus variable OM&R.

On the other hand, since the transfer to R1 would require use of CVP facilities, it must pay the CVP cost-of-service rate (the sum of the transfer base rate and the transfer service rate), which is $12.95/acre-foot (11.84 + 1.11). In addition, the use of CVP facilities requires payment of the $6 Restoration charge.

As a result, the net transfer cost is a credit of $-7.9 /acre-foot (12.95 + 6 - 26.90).

To R14 (CVP buyer). This transfer saves $26.90/acre-foot in SWP energy plus variable OM&R costs.

It is charged the CVP cost of service rate to R14, $28.12/acre-foot (25.51 + 2.61), plus the $6 Restoration charge.

As a result, the net transfer cost is $7.22/acre-foot (28.12 + 6 -26.90).

To D5 (CVP buyer). This transfer reduces SWP energy and variable OM&R cost by $39.64/acre-foot . It is charged the CVP M&I cost of service to D5, $156.72/acre-foot (150.65 + 6.07), plus the $12 M&I Restoration charge.

As a result, the net transfer cost is $129.08/acre-foot (156.72 + 12 - 39.64).

To D10 (SWP buyer). The transfer is between two SWP users so the additional transfer cost is the difference between two TV's, or $115.92 /acre-foot (155.56-39.64).

To REF8. Supplies to REF8 are conveyed through the SWP. The energy and variable OM&R charges for the SWP decrease by \$3.62/acre-foot (from 26.90 to 23.28).

MODEL CONFIRMATION RUN
TESTING THE MODEL AGAINST THE 1991 DROUGHT WATER BANK

In 1991, the DWR instituted a drought water bank which included a significant land fallowing component. The State offered farmers a fixed price of \$125 per net acre-foot of water made available by fallowing land. According to a report prepared for DWR (Howitt, et al., 1992), approximately 166,000 acres of farmland were fallowed, yielding about 380,000 acre-feet of water. Fallowing occurred from Shasta County to as far south as San Joaquin County.

To test the reasonableness of the CVPTM's estimates, the state water bank was simulated using the model. The state's land fallowing offer was simulated by creating a water transfer demand at the Delta, with an extremely elastic demand function at the \$125 per acre-foot price. Specifically, a linear demand function with an elasticity of -25 was used that allowed as one possible outcome the observed level of 380,000 acre-feet at \$125 per acre-foot. With the high elasticity, this is roughly equivalent to offering \$125/acre-foot for any quantity of water. CVPTM was then solved subject to 1991 hydrologic conditions.

Results of the simulation were quite reasonable, and somewhat conservative. The net water sold into the simulated water bank was 314,000 acre-feet at just over \$126 per acre-feet. The locations of water sold were also roughly consistent with those observed during the bank, reported by county in Howitt et al. (1992). The model's hydrologic regions do not correspond well with county lines so a direct comparison is difficult. Regions predicted to sell water were Region 1 (25,000 acre-feet), Region 3 (61,000 acre-feet), Region 4 (156,000 acre-feet), and Region 5 (72,000 acre-feet). Figure II-4 presents the comparisons.

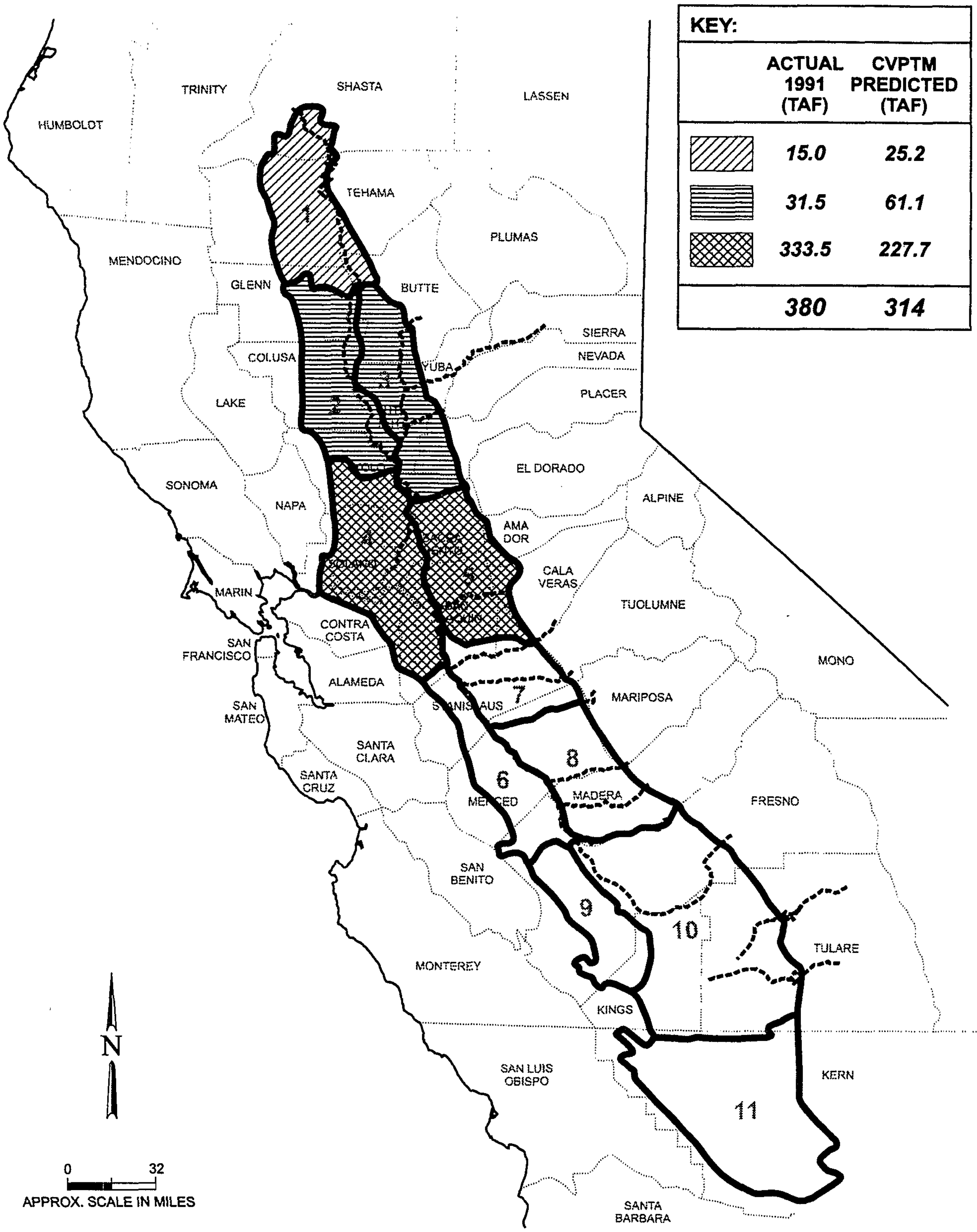

FIGURE II-4

SIMULATION OF 1991 STATE DROUGHT BANK
ACTUAL vs CVPTM PREDICTED WATER SOLD FROM FALLOWING

CHAPTER III

APPLICATION TO THE PEIS

Chapter III

APPLICATION TO THE PEIS

INTRODUCTION

This chapter describes the specific assumptions and constraints used for the Transfers Without CVPIA analysis and for Supplemental Analyses 1e, 1f, 2b, 2c, 3a, and 4a. The limitations for use of CVPTM are addressed. The results of transfer analysis for all Supplemental Analyses are reported in the Water Transfer Opportunities Technical Appendix.

TRANSFERS WITHOUT CVPIA

Besides the main assumptions and constraints, as discussed in Chapter II, the additional assumptions used to assess water transfers without CVPIA are described below. Transfers have occurred and would have continued to occur without CVPIA. This assessment is needed to provide a basis for measuring only the incremental impact of CVPIA on opportunities for water transfers. The assessment adopts the assumptions of the No-Action Alternative and adds some additional assumptions regarding water transfers. Further discussion of these assumptions and the results of the analysis are provided in the Water Transfer Opportunities Technical Appendix.

- CVP water delivered under water service or San Joaquin River exchange contracts cannot be transferred to non-CVP contractors.
- M&I water transfer demand functions derived from the No-Action Alternative analysis are shown in Table III-1 for both the average and dry condition. A transfer demand function is defined for each M&I region as $Q = a + b*P$, where Q is the amount of net water transferred (1,000 af), P is the price of transferred water per unit ($/af) measured at the M&I destination, and a and b are the intercept and slope, respectively.
- Average year transfers are assumed to bear a 50 percent deficiency in a dry year condition.
- The Delta export and major conveyance capacities available for the No-Action Alternative are presented in Table III-2.

SUPPLEMENTAL ANALYSES 1e and 1f

The transfer analysis under Supplemental Analyses 1e and 1f is based upon the same assumptions as in the Transfers Without CVPIA analysis, except that:

- Alternative 1 hydrology and water pricing are used.

TABLE III-1

M&I WATER TRANSFER DEMAND FUNCTIONS
TRANSFERS WITHOUT CVPIA

M&I Regions	Description of Major Water Users	Average Year (Long Run)			Dry Year (Short Run)		
		Intercept	Slope	Maximum Demand (1,000 af)	Intercept	Slope	Maximum Demand (1,000 af)
D1	Sacramento Area	355	-5.46	0.0	324	-4.440	0.0
D2	Shasta and Redding Area	85	-1.31	0.0	72	-0.980	0.0
D3	North Bay Aqueduct	N/A	N/A	0.0	55	-0.080	12.8
D4	Contra Costa WD	95	-0.22	2.1	83	-0.100	16.7
D5	San Felipe Division	N/A	N/A	0.0	473	-0.550	155.3
D6	South Bay Aqueduct						
D7	Coastal Branch	33	-0.02	5.1	28	-0.004	13.1
D8	Central Valley Cities	182	-1.07	0.0	165	-0.750	0.0
D9	KCWA and Bakersfield	118	-0.94	0.0	123	-0.710	17.1
D10	Southern California	1,069	-1.33	100.0	1,614	-1.330	350.0

NOTES:
For the method of estimating these demand functions, refer to Municipal Water Cost M/M Technical Appendix.
The transfer demand for D5 and D6 is a joint demand function. The two regions have two separate conveyance facilities to transfer water into the regions but they can normally exchange water.
In all cases, except D10, the maximum is defined as the amount of shortage. The maximum demand from Southern California (D10) was identified by planning documents provided by the MWDSC.
N/A indicates no water transfer demand.

TABLE III-2

DELTA EXPORT AND MAJOR CONVEYANCE CAPACITIES
AVAILABLE FOR WATER TRANSFERS WITHOUT CVPIA

Major Pumping and Conveyance Facilities Considered	Total Remaining Capacities Between July and January (1,000 af)	
	Average Year (1922 - 1990)	Dry Year (1928 - 1934)
Remaining Capacity at Tracy	316	634
Remaining Capacity at Banks	716	1370
Remaining Capacity Below Node 45 (DMC)	262	545
Remaining Capacity in the Hetch-Hetchy System	N/A	48
Remaining Capacity in the South Bay Aqueduct	N/A	71
Remaining Capacity in the San Felipe Division	N/A	52

NOTES:
N/A means not applicable since there are no transfer demands through these systems in an average year condition.
Monthly operations results were not available for the Hetch-Hetchy System. Remaining capacity shown is an annual estimate.
Remaining capacities shown for the South Bay Aqueduct and the San Felipe Division are based on a comparison of monthly facility capacity vs. monthly average deliveries from PROSIM.

- 1e incorporates the transfer charges described in CVPIA. 1f adds an additional $50 per acre-foot charge for CVP water transferred.
- CVP water delivered under water service or San Joaquin River exchange contracts can be transferred.
- CVPIA Section 3405(a)(1) (B) requires that transfers involving more than 20 percent of the CVP water within any contracting district or agency shall be subject to review and approval by such district or agency. CVPTM adopts 20 percent of surface water as the upper bound for transfers out of a region to minimize the third party impact. This is also consistent with state law for transfers involving fallowed land (CWC 1745.05(b)).
- M&I water transfer demand functions for 1e and 1f are shown in Table III-3.
- The Delta export and major conveyance capacities available for 1e and 1f are presented in Table III-4.

TABLE III-3

M&I WATER TRANSFER DEMAND FUNCTIONS SUPPLEMENTAL ANALYSES 1e AND 1f

M&I Regions	Description of Major Water Users	Average Year (Long Run)			Dry Year (Short Run)		
		Intercept	Slope	Maximum Demand (1,000 af)	Intercept	Slope	Maximum Demand (1,000 af)
D1	Sacramento Area	357	-5.46	0.0	324	-4.440	0.0
D2	Shasta and Redding Area	85	-1.31	0.0	72	-0.980	0.0
D3	North Bay Aqueduct	N/A	N/A	0.0	52	-0.080	12.8
D4	Contra Costa WD	96	-0.22	3.0	85	-0.100	16.7
D5	San Felipe Division	N/A	N/A	0.0	471	-0.550	155.3
D6	South Bay Aqueduct						
D7	Coastal Branch	31	-0.02	4.2	28	-0.005	13.1
D8	Central Valley Cities	184	-1.07	0.0	164	-0.750	0.0
D9	KCWA and Bakersfield	114	-0.94	0.0	120	-0.710	17.1
D10	Southern California	1,095	-1.33	100.0	1,541	-1.330	350.0

NOTES:
For the method of estimating these demand functions, refer to Municipal Water Cost Technical Appendix.
The transfer demand for D5 and D6 is a joint demand function. The two regions have two separate conveyance facilities to transfer water into the regions but they can normally exchange water.
In all cases, except D10, the maximum is defined as the amount of shortage. The maximum demand from Southern California (D10) is identified by the planning documents provided by the MWDSC.
N/A indicates no water transfer demand.

TABLE III-4

DELTA EXPORT AND MAJOR CONVEYANCE CAPACITIES AVAILABLE FOR WATER TRANSFERS: ALTERNATIVES 1e AND 1f

Major Pumping and Conveyance Facilities Considered	Total Remaining Capacities Between January and July (1,000 af)	
	Average Year (1922 - 1990)	Dry Year (1928 - 1934)
Remaining Capacity at Tracy	451	756
Remaining Capacity at Banks	677	1293
Remaining Capacity Below Node 45 (DMC)	382	635
Remaining Capacity in the Hetch-Hetchy System	N/A	48
Remaining Capacity in the South Bay Aqueduct	N/A	68
Remaining Capacity in the San Felipe Division	N/A	65

LEGEND:
N/A = not applicable since there are no transfer demands through these systems in an average year condition.

SUPPLEMENTAL ANALYSES 2b and 2c

The transfer analysis under Supplemental Analyses 2b and 2c is based upon the same assumptions as in 1, except that:

- Alternative 2 hydrology and water pricing are used.

- 2b incorporates the transfer charges described in CVPIA. 2c adds an additional $50 per acre-foot charge for CVP water transferred.

- The M&I water transfer demand functions and the Delta export and major conveyance capacities available for water transfers are the same as for 1e and 1f, as shown in Tables III-3 and III-4.

- Under Alternative 2, water would be acquired for fish and wildlife restoration from willing sellers on the Stanislaus, Tuolumne, and Merced rivers. The total amount of water acquired is estimated to be 160,000 acre-feet, as shown in Table III-5. Water is also acquired from willing sellers to provide Level 4 refuge supplies.

SUPPLEMENTAL ANALYSIS 3a

The transfer analysis under Supplemental Analysis 3a is based upon the same assumptions as in 2b, except that:

- Alternative 3 hydrology and operations are used.

- The M&I water transfer demand functions and the Delta export and major conveyance capacities available for water transfers are estimated for 3a as shown in Tables III-6 and III-7.

- Compared to Alternative 2, more water is purchased in Alternative 3 on the Stanislaus, Tuolumne, and Merced rivers in order to increase the instream flows. In addition, Alternative 3 would acquire water from willing sellers on the Yuba River, Calaveras River, and Mokelumne River. The total amount of water acquired for instream flow under Alternative 3 is estimated to be 765,000 acre-feet, and is shown in Table III-8. Water is also acquired from willing sellers to provide Level 4 refuge supplies. The cost estimates for the acquired water are reported in Water Transfer Opportunities Technical Appendix.

TABLE III-5

ESTIMATES OF ACQUIRED WATER, ALTERNATIVE 2

Rivers	Long-Term Average Water Acquisition Amount (taf/year) (1) (2)
Yuba River	0
Calaveras River	0
Mokelumne River	0
Stanislaus River	51
Tuolumne River	60
Merced River	49
Total Average	160

NOTES:
(1) The cost estimate does not include Level 4 incremental refuge water acquisitions.
(2) Estimated by SANJASM and PROSIM.

TABLE III-6

M&I WATER TRANSFER DEMAND FUNCTIONS SUPPLEMENTAL ANALYSIS 3a

M&I Regions	Description of Major Water Users	Average Year (Long Run)			Dry Year (Short Run)		
		Intercept	Slope	Maximum Demand (1,000 af)	Intercept	Slope	Maximum Demand (1,000 af)
D1	Sacramento Area	356	-5.46	0.0	342	-4.440	0.0
D2	Shasta and Redding Area	86	-1.31	0.0	72	-0.980	0.0
D3	North Bay Aqueduct	N/A	N/A	0.0	49	-0.080	7.0
D4	Contra Costa WD	96	-0.22	2.4	85	-0.100	18.2
D5	San Felipe Division	N/A	N/A	0.0	454	-0.550	136.5
D6	South Bay Aqueduct						
D7	Coastal Branch	29	-0.02	2.0	26	-0.005	10.4
D8	Central Valley Cities	183	-1.07	0.0	165	-0.750	0.0
D9	KCWA and Bakersfield	108	-0.94	0.0	115	-0.70	8.0
D10	Southern California	1,118	-1.33	100.0	1455	-1.330	350.0

NOTES:
For the method of estimating these demand functions, refer to Municipal Water Cost Technical Appendix.
The transfer demand for D5 and D6 is a joint demand function. The two regions have two separate conveyance facilities to transfer water into the regions but they can normally exchange water.
In all cases, except D10, the maximum is defined as the amount of shortage. The maximum demand from Southern California (D10) is identified by the planning documents provided by the MWDSC.
N/A indicates no water transfer demand.

TABLE III-7

DELTA EXPORT AND MAJOR CONVEYANCE CAPACITIES AVAILABLE FOR WATER TRANSFERS: SUPPLEMENTAL ANALYSIS 3a

Major Pumping and Conveyance Facilities Considered	Total Remaining Capacities Between January and July (taf)	
	Average Year (1922 - 1990)	Dry Year (1928 - 1934)
Remaining Capacity at Tracy	401	653
Remaining Capacity at Banks	574	1168
Remaining Capacity Below Node 45 (DMC)	345	551
Remaining Capacity in the Hetch-Hetchy System	N/A	48
Remaining Capacity in the South Bay Aqueduct	N/A	71
Remaining Capacity in the San Felipe Division	N/A	65

LEGEND:
N/A = not applicable since there are no transfer demands through these systems in an average year condition.

TABLE III-8

ESTIMATES OF ACQUIRED WATER SUPPLEMENTAL ANALYSES 3a AND 4a

Rivers	Long-term Average Water Acquisition Amount (taf/year) (1) (2)
Yuba River	92
Calaveras River	27
Mokelumne River	66
Stanislaus River	192
Tuolumne River	196
Merced River	192
Total Average	765

NOTES:
(1) The estimate does not include Level 4 incremental refuge water acquisitions.
(2) Estimated by SANJASM and PROSIM.

SUPPLEMENTAL ANALYSIS 4a

The transfer analysis under Supplemental Analysis 4a is based upon the same assumptions as in 3a, except that:

- Alternative 4 hydrology and operations are used.

- The M&I water transfer demand functions and the Delta export and major conveyance capacities available for water transfers are estimated for 4a as shown in Tables III-9 and III-10.

- The water acquired for instream flow under Alternative 4 is the same as in Alternative 3, and is estimated to be 765,000 acre-feet as shown in Table III-8. The cost estimates for the acquired water are reported in the Water Transfer Opportunities Technical Appendix.

TABLE III-9

M&I WATER TRANSFER DEMAND FUNCTIONS
SUPPLEMENTAL ANALYSIS 4a

<table>
<tr><th rowspan="2">M&I Regions</th><th rowspan="2">Description of Major Water Users</th><th colspan="3">Average Year (Long Run)</th><th colspan="3">Dry Year (Short Run)</th></tr>
<tr><th>Intercept</th><th>Slope</th><th>Maximum Demand (1,000 af)</th><th>Intercept</th><th>Slope</th><th>Maximum Demand (1,000 af)</th></tr>
<tr><td>D1</td><td>Sacramento Area</td><td>357</td><td>-5.46</td><td>0.0</td><td>342</td><td>-4.440</td><td>0.0</td></tr>
<tr><td>D2</td><td>Shasta and Redding Area</td><td>86</td><td>-1.31</td><td>0.0</td><td>72</td><td>-0.980</td><td>0.0</td></tr>
<tr><td>D3</td><td>North Bay Aqueduct</td><td>N/A</td><td>N/A</td><td>0.0</td><td>54</td><td>-0.090</td><td>12.8</td></tr>
<tr><td>D4</td><td>Contra Costa WD</td><td>97</td><td>-0.22</td><td>2.4</td><td>85</td><td>-0.110</td><td>17.8</td></tr>
<tr><td>D5</td><td>San Felipe Division</td><td rowspan="2">N/A</td><td rowspan="2">N/A</td><td rowspan="2">0.0</td><td rowspan="2">477</td><td rowspan="2">-0.550</td><td rowspan="2">159.8</td></tr>
<tr><td>D6</td><td>South Bay Aqueduct</td></tr>
<tr><td>D7</td><td>Coastal Branch</td><td>32</td><td>-0.02</td><td>2.0</td><td>29</td><td>-0.005</td><td>12.9</td></tr>
<tr><td>D8</td><td>Central Valley Cities</td><td>184</td><td>-107</td><td>0.0</td><td>165</td><td>-0.750</td><td>0.0</td></tr>
<tr><td>D9</td><td>KCWA and Bakersfield</td><td>118</td><td>-0.94</td><td>0.0</td><td>123</td><td>-0.710</td><td>16.7</td></tr>
<tr><td>D10</td><td>Southern California</td><td>1,225</td><td>-1.33</td><td>100.0</td><td>1608</td><td>-1.330</td><td>350.0</td></tr>
</table>

NOTES:
For the method of estimating these demand functions, refer to Municipal Water Cost Technical Appendix.
The transfer demand for D5 and D6 is a joint demand function. The two regions have two separate conveyance facilities to transfer water into the regions but they can normally exchange water.
In all cases, except D10, the maximum is defined as the amount of shortage. The maximum demand from Southern California (D10) is identified by the planning documents provided by the MWDSC.
N/A indicates no water transfer demand.

TABLE III-10

DELTA EXPORT AND MAJOR CONVEYANCE CAPACITIES AVAILABLE FOR WATER TRANSFERS: SUPPLEMENTAL ANALYSIS 4a

<table>
<tr><th rowspan="2">Major Pumping and Conveyance Facilities Considered</th><th colspan="2">Total Remaining Capacities Between January and July (taf)</th></tr>
<tr><th>Average Year (1922 - 1990)</th><th>Dry Year (1928 - 1934)</th></tr>
<tr><td>Remaining Capacity at Tracy</td><td>429</td><td>757</td></tr>
<tr><td>Remaining Capacity at Banks</td><td>693</td><td>1370</td></tr>
<tr><td>Remaining Capacity Below Node 45 (DMC)</td><td>355</td><td>633</td></tr>
<tr><td>Remaining Capacity in the Hetch-Hetchy System</td><td>N/A</td><td>48</td></tr>
<tr><td>Remaining Capacity in the South Bay Aqueduct</td><td>N/A</td><td>71</td></tr>
<tr><td>Remaining Capacity in the San Felie Division</td><td>N/A</td><td>65</td></tr>
</table>

LEGEND:
N/A= not applicable since there are no transfer demands through these systems in an average year condition.

SENSITIVITY ANALYSIS ALLOWING GROUNDWATER SUBSTITUTION

Because of uncertainty in how state law may apply in the future to the substitution of groundwater for transferred water, a separate analysis was done for transfers without CVPIA and for supplemental analyses 1e and 2b. These analyses use the same assumptions as described above except that they allow groundwater substitution. Results of these sensitivity analyses are described in the Water Transfer Opportunities Technical Appendix.

LIMITATIONS FOR MODELING OF WATER TRANSFERS FOR THE PEIS

As discussed earlier, CVPTM is a "planning model" to evaluate CVPIA provisions and conduct other sensitivity and policy analysis. It is not used to estimate physical capacity to move water or identify who will be affected. It is not meant to be used to predict which agencies will transfer water either as buyers or sellers. In addition, the estimates from CVPTM focus on interregional transfers. Local transfers within a region, especially between agricultural users are not explicitly counted in this analysis. Water transfer assumptions, charges, available capacities, and conveyance losses are based on conversations with Reclamation personnel and on information available at the time the analysis was being designed. These assumptions are believed to be reasonable for a programmatic analysis of the impact of CVPIA provisions on water transfers, but should not be viewed as final determinations of Reclamation policy.

CHAPTER IV

BIBLIOGRAPHY

Chapter IV

BIBLIOGRAPHY

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ATTACHMENT A

CVPTM MATHEMATICAL DESCRIPTION

Attachment A

CVPTM MATHEMATICAL DESCRIPTION

The Central Valley Production and Transfer Model (CVPTM) is an augmented version of the Central Valley Production Model (CVPM) with water transfers. CVPM is a multi-regional model of irrigated agricultural production and economics that simulates the decisions of agricultural producers in the Central Valley of California. The model includes 22 crop production regions and 26 categories of crops. Without water transfers, CVPM estimates an implicit water value by region which is the marginal increase in agricultural net revenues from an additional unit of water supply. CVPTM uses these implicit water values to describe a supply function for transferred water. It includes 11 agricultural regions (aggregated from the 22 regions), which are either potential buyers or sellers, and 10 M&I regions that are potential buyers.

This attachment presents a brief mathematical description of CVPTM.

OBJECTIVE FUNCTION

The CVPTM objective function can be described, with some simplification, as

$$
\begin{aligned}
\mathbf{Object} = & \sum_R\sum_C[\mathbf{YLD}_{R,C}\bullet\mathbf{P}_C\text{-}\mathbf{IRCST}_{R,C}\text{-}\mathbf{OTCST}_{R,C}]\bullet\mathbf{XN}_{R,C}\text{-}\sum_R\sum_W\mathbf{WP}_{R,W}\bullet\mathbf{WAT}_{R,W} \\
& +\sum_R\sum_C\mathbf{CS}(\mathbf{XN}^{R,C}) \\
& -\sum_R\sum_Q\sum_W\mathbf{TRCOST}_{R,Q,W}\bullet\mathbf{WTRAN}_{R,QW}\mathbf{lAT}_{R,Q} \\
& +\sum_D\sum_Q\sum_W\mathbf{TRFRAC}_{D,Q,W}\mathbf{lAT}_{R,Q}\bullet[\mathbf{WRPI}_D\text{-}\mathbf{TRCOST}_{D,Q,W}] \\
& +\sum\mathbf{TICS}(\mathbf{TRFRAC}_{D,Q}\bullet\mathbf{WTRAN}_{D,Q,W})
\end{aligned}
$$

where

R, Q	= Central Valley agricultural production regions
C	= crops
W	= water sources, including CVP contract water, CVP water rights water, State Water Project water, local surface water, and groundwater
YLD, P	= crop yields and output prices
IRCST	= annualized irrigation system cost
OTCST	= other production costs
XN	= irrigated acres
D	= M&I regions
WP	= water cost per acre-foot

WAT	= applied irrigation water
CS	= consumer surplus for agricultural product users
TRCOST	= conveyance cost and other transfer cost per acre-foot of transferred water
WTRAN	= the amount of water transferred out of the selling region
AT	= water transfer feasibility matrix
TRFRAC	= ratio of sold water to received water
WPRI	= price of transferred water received by M&I users
MICS	= consumer surplus for M&I water users

The objective function consists of two parts. The first part (the first two lines) is a simplified representation of CVPM's objective function. It is the sum of producer's surplus (measured as net revenue from irrigated crop production) and consumer surplus CS.[1] The second part extends the CVPM's objective function by including water transfers. It first subtracts the total conveyance costs for transfers between agricultural regions, then, for water sold to M&I regions, it adds the sellers' net revenue received from water sold and buyers' gains from water bought. Sellers' net revenue received equals the gross revenue received minus transfer costs. The buyers' gains are defined as consumer surplus for M&I (MICS).[2] CVPTM solves for the water price, crop mix, amount of irrigated land, and level of water transfers that maximize the sum of net revenue and consumer surplus for both agricultural production and water transfers.

WATER TRANSFER BALANCE EQUATION

$$\text{SOURCET (RW)}\ldots WAT_{R,W}+\sum_{QD} WTRAN_{QD,R,W} | AT$$
$$\leq BWATER_{R,W}+\sum_{Q} TRFRAC*WTRAN_{R,Q,W} | AT$$

The water balance equation for each selling region, R, states that water used for crop production plus gross transfer out of the region must be less than or equal to water sources available plus net transfers into the region. Net transfer (TRFRAC*WTRAN) is measured at the destination. It equals the gross transfer measured at the selling region minus transfer conveyance losses and Delta outflow requirements for cross Delta transfers. The 1994 Bay-Delta Plan Accord generally restricts exports to be no greater than 35% of Delta inflow between February and June and no greater than 65% of Delta inflow between July and January. For the CVPIA analysis, CVPTM assumed that buyers would attempt to transfer water across-Delta only during the July through January period.

DELTA EXPORT CAPACITY AVAILABLE FOR WATER TRANSFERS

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[1] CS depends on the form of demand functions used. For simplicity, we use a general term here.

[2] We use a general term here for simplicity.

$$\text{DELTPUMP}..\sum_{RDS}\sum_{QN}\sum_{SW}\text{TRFRAC}_{RDS,QN}\bullet\text{WTRAN}_{RDS,QN,SW}|\text{AT} \leq \text{DELTALIM}$$

Water transfers from the north of Delta (QN) to the south of Delta (RDS) are subject to the Delta export capacities available for water transfers (DELTALIM). For example, the California Department of Water Resources (1994) reports that the total of CVP and SWP export capacities available for water transfers are estimated to be about 0.6 million acre-feet in an average year condition and 1.4 million acre-feet in a dry year condition. CVPTM obtains the estimates of Delta export capacities for water transfers from PROSIM. For example, under the PEIS No-Action Alternative, PROSIM estimates that the available Delta export capacities for water transfers during the July through January period are 1.32 million acre-feet for average years and 2.1 million acre-feet for dry years.

M&I WATER TRANSFER DEMAND FUNCTIONS

$$\text{PRICE(D)}..\sum_{Q}\sum_{W}\text{TRFRAC}_{D,QN}|\text{AT} = \text{MIINT}_{D}\text{-MSLP}_{D}\bullet\text{WPRI}_{D}$$

CVPTM includes water transfer demand functions for 10 major groups of M&I providers who may participate in Central Valley water markets. The demand functions are developed based on water shortage estimates, capacity limitations, costs of alternative supplies, and costs of shortages. The price and quantity of M&I water are measured at the treatment plant. Therefore, the price of M&I water purchased (WPRI) includes seller's price plus transfer costs, and the quantity is the net water received (TRFRAC*WTRAN).

WATER TRANSFER DEMAND BY FISH AND WILDLIFE

There are two options in modeling water acquisition for fish and wildlife restoration. One would be to include a set of demand functions for instream fish flow requirements and refuge water needs. These demand functions would be treated just like M&I demand functions such that the demands can be met either by local sources or by water transfers from other locations. Using this option, CVPTM could group various fish and wildlife management areas into several demand regions based on similarity of geographical location and potential supply sources within the Central Valley. The second option would be to treat instream flows and refuge demands as physical constraints on water available to other users in regions in which the streams or refuge sites are located. In other words, these demands would be supplied during the hydrological simulations, reducing water available for other users, so no specific demand functions would be included in CVPTM. In the second option, average unit cost estimates for acquired water would be based on the water transfer results for a given alternative so that competition from M&I and other water buyers would be included. The second approach is used for the PEIS analysis.

TRANSFER FEASIBILITY MATRIX AND CONVEYANCE COST

A water transfer feasibility matrix (AT) represents the physical possibility to move water from one location to another. It is a matrix of ones or zeros, where one represents a feasible water transfer and zero represents non-feasibility. CVPTM allows two types of transfers: direct and exchange. In a direct transfer, water that would have moved to the seller is instead moved to the buyer. There are only two parties to the transfer. In an exchange transfer, there are at least three parties to the transfer, and the buyer does not usually obtain the seller's water. For example, in an exchange, the seller provides water to a willing third party, and the buyer receives water from another source that would have gone to the third party.

Water transfer conveyance cost (TRCOST) depends on the source, destination, type of water, and conveyance facility used. Chapter II of this Technical Appendix describes the various conveyance costs that are included. In addition, TRCOST includes other transfer related costs such as transactions costs and CVPIA Restoration Fund charges. For example, if CVP agricultural water is transferred to a non-CVP M&I users, then a $25 per acre-foot CVPIA Restoration Fund charge is added to the cost.

OTHER CONSTRAINTS AND OPTIONS

Other constraints and options that can be included in the CVPTM are:

- Restrictions on the transferability of different classifications of water. For example, water delivered by the CVP under San Joaquin River Exchange Contracts can be designated as not transferable under the No-Action Alternative:
- Groundwater transfer or substitution of groundwater for transferred water can be either allowed or restricted:
- Savings from irrigation improvements can be designated as not transferable, to assure that "real water" is being transferred":
- Cumulative transfers from a region can be restricted to to some portion of the surface water supply, to limit third party impacts:
- Only ET of applied water or other irrecoverable losses may be designated as transferable.

CENTRAL VALLEY PROJECT IMPROVEMENT ACT PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT

DRAFT METHODOLOGY/MODELING TECHNICAL APPENDIX

Municipal Water Costs M/M

September 1997

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

ACWD	Alameda County Water District
af	acre-foot (acre-feet)
BMP	best management practice
CCWD	Contra Costa Water District
CRA	Colorado River Aqueduct
CUWA	California Urban Water Agencies
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CVPM	Central Valley Production Model
CVPTM	Central Valley Production Transfer Module
DWR	California Department of Water Resources
EBMUD	East Bay Municipal Utility District
FCWCD	Flood Control and Water Conservation District
ERM	Economic Risk Model
KCWA	Kern County Water Agency
M&I	municipal and industrial
MWD	Metropolitan Water District of Southern California
NBA	North Bay Aqueduct
O&M	operation and maintenance
PAD	potentially affected demand
PEIS	Programmatic Environmental Impact Statement
PROSIM	Project Simulation Model of the Central Valley Project
Reclamation	U.S. Bureau of Reclamation
RGO	residential, government, and other
SANJASM	San Joaquin River and Tributaries Simulation Model
SBA	South Bay Aqueduct
SCVWD	Santa Clara Valley Water District
SCWA	Sacramento County Water Agency
SMUD	Sacramento Municipal Utility District
SWP	State Water Project
SWRCB	State Water Resources Control Board
taf	thousand acre-feet
WTAC	willingness to accept compensation
WTP	willingness to pay

CHAPTER I

INTRODUCTION

Chapter I

INTRODUCTION

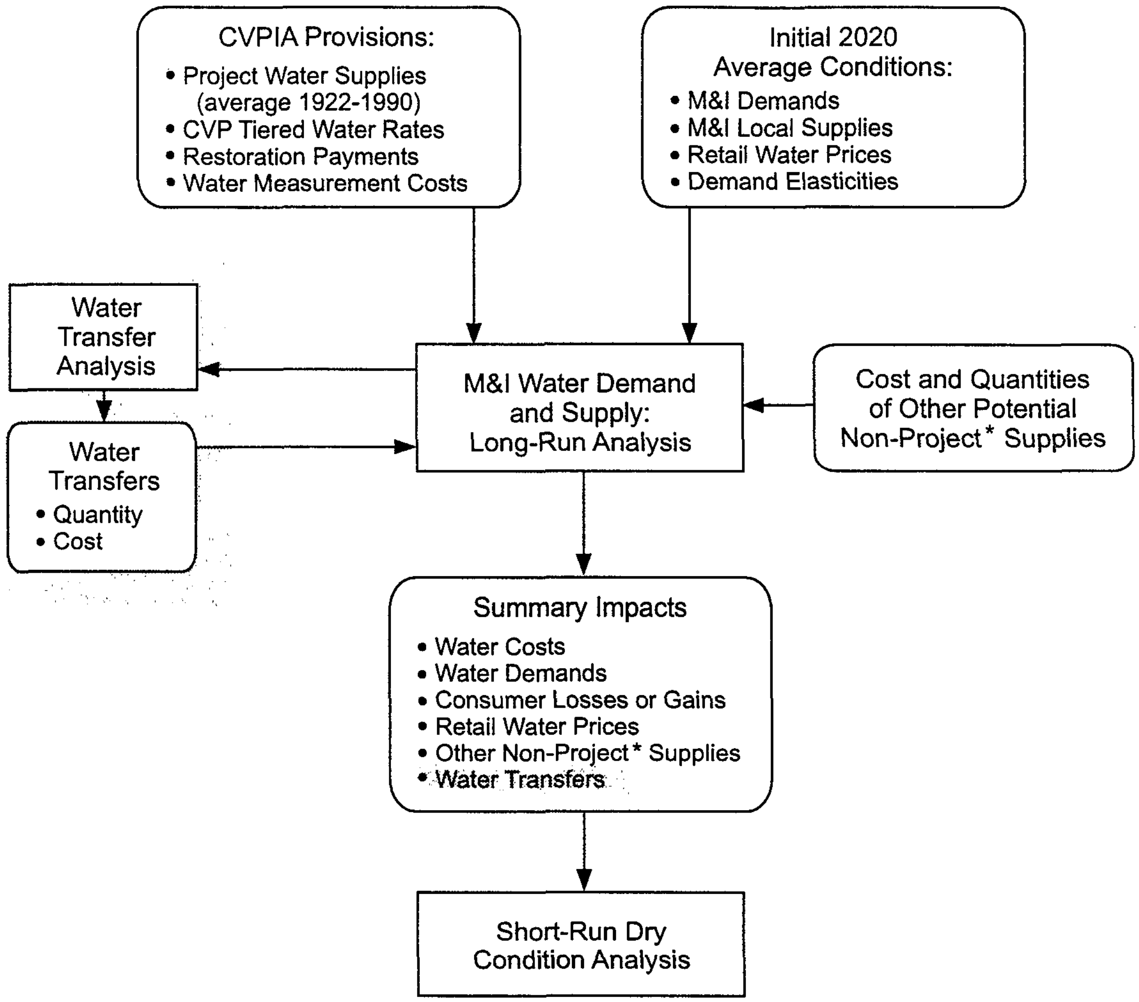
This appendix describes techniques used in the analysis of municipal and industrial (M&I) water use and costs. First, the scope of the analysis is described generally in terms of the conduct of the analysis and the M&I providers included. The general approach to estimation of residential water demand functions and end user shortage costs is explained. Alternative demand management and water supply options are presented and discussed. M&I water transfer demand functions are developed by the municipal water cost analysis and are provided to the water transfer analysis. The technique used to estimate these demand functions and the costs of other new supplies are provided. Finally, data sources including the costs of metering, conservation, and tiered price provisions are discussed.

The analysis of M&I water use and costs is required because the CVPIA may have several types of effects on M&I water providers and the end users they serve. These effects include changes in water supply, direct cost increases in the form of restoration payments and tiered water pricing, costs of water conservation and measurement requirements, and effects of water acquisition and CVPIA water transfer provisions on water transfer costs.

The modeling effort serves the following purposes:

- estimate the costs and benefits of changes in M&I water supplies caused by Central Valley Project Improvement Act (CVPIA) provisions;
- estimate the costs to M&I providers and their customers associated with other CVPIA provisions; and
- estimate M&I water transfer demand functions for use in the water transfer analysis, and with the water transfer analysis, estimate effects of water transfers on M&I water costs.

Modeling procedures are summarized in Figure I-1. This appendix explains each of the steps in Figure I-1 and demonstrates how the modeling of alternatives was conducted.



Notes:

* Non-Project refers to other potential sources of water supply not available through CVP or SWP or through water transfers. Sources could include local reclamation, desalination, and new local surface storage or conjunctive use projects.

Shaded areas indicate supplemental analysis with water transfers.

FIGURE I-1

STEPS IN M&I ECONOMICS ANALYSIS

CHAPTER II

DESCRIPTION

Chapter II

DESCRIPTION

In summary, the M&I water use and cost analysis considers water supply, demand, costs, and value. Water supplies are provided from hydrology models and other sources, and in the case of the water transfer analysis, from the Central Valley Production and Transfer Model (CVPTM). The CVPTM is described in its own technical appendix.

Economic costs to M&I providers include costs of new water supplies, costs of drought management, revenues lost from reduced water sales, and costs of customer water shortage. These latter costs are estimated using retail demand functions derived from data on retail price, demand, and demand elasticity. Much of the analysis is conducted within a spreadsheet model with simultaneous components to calculate relationships between revenue, water price, demand, and costs.

For any alternative, with or without water transfers, a long-run analysis is conducted first using 1922 through 1990 average hydrology. Changes in costs caused by changes in imported water supplies, as estimated by the hydrology models, or other cost changes caused by CVPIA provisions are passed on to customers. The long-run aspect of the analysis means that M&I provider revenues must equal costs and that retail water price adjusts until this constraint is met, but the quantity of water demand is also affected by the price.

The dry condition analysis, based on 1928 through 1934 hydrology, is quite different. For any alternative, water price, change in quantity of demand, and change in permanent supplies from the average condition analysis are carried into the dry condition. That is, the amount of shortage and economic costs of drought depend on conditions going into the drought. Mandatory drought conservation is required before any make-up supplies can be acquired. The costs of mandatory drought conservation are program costs paid by the provider to implement the program, lost net revenues of water providers, and lost consumer surplus of retail buyers. Consumer surplus is value of water to users, above what is paid for it, that is lost because of the mandatory conservation. Drought conservation can accommodate only so much shortage, estimated as a fixed percent of demands, so providers acquire make-up supplies to eliminate any shortage in excess of the drought conservation requirement. Costs of make-up supplies are part of the total cost of the dry condition.

MODEL STUDY AREA

The analysis includes 11 potentially affected M&I providers aggregated into four groups for purposes of display. A provider is potentially affected if it has a Central Valley Project (CVP) contract, if it could be affected by water acquisition for fish and wildlife, or if it has the physical ability to participate in CVP water transfers.

SACRAMENTO VALLEY GROUP

The Sacramento Valley Group consists of CVP water users in the vicinity of Redding and Sacramento. The Redding group includes several CVP providers on the upper Sacramento River, most notably the City of Redding. Redding has CVP contract water as well as water rights. The Sacramento area covers the cities of West Sacramento, Sacramento, the entire CVP service area near Sacramento, and the Placer County Water Agency. Folsom Lake and the Folsom South Canal of the CVP currently serve the Sacramento area with American River water. Important users of Folsom Lake water include Roseville and San Juan Suburban. The Sacramento Municipal Utility District (SMUD) is the major user of Folsom South Canal water.

BAY AREA GROUP

The Bay Area Group consists of most of the Bay Area except for Marin and Sonoma counties and parts of Napa and Solano counties. The group includes SWP entitlement holders served by the North Bay Aqueduct (NBA) of the SWP and others who have used or could use this facility in exchanges. Two water districts are served by the NBA: Napa County Flood Control and Water Conservation District (FCWCD), and Solano County FCWCD. The Napa County FCWCD serves State Water Project (SWP) water in southern Napa County. The Solano County FCWCD serves the cities of Vallejo, Vacaville, Fairfield, Benicia, and Suisun. In addition to SWP entitlement water, Vallejo conveys water rights water through the NBA, and the two districts have transferred water and obtained surplus water through the NBA.

The group includes parts of Alameda, Contra Costa, Santa Clara, San Francisco, and San Mateo counties in the South Bay, and is potentially affected by the CVPIA through SWP supplies, transfers through the South Bay Aqueduct, through Tuolumne River supplies purchased for supplemental water, and through CVP contract supplies. The group includes three SWP providers in the South Bay: Alameda County Water District (ACWD), Alameda County Zone 7, and Santa Clara Valley Water District (SCVWD). SCVWD is also served by the San Felipe Unit of the CVP and wholesales water in a large part of the south San Francisco Bay. This water supply and San Felipe M&I supply for San Benito Water District are included.

Contra Costa Water District (CCWD) provides CVP municipal water in Contra Costa County for the cities of Antioch, Concord, Martinez, Pittsburg, Walnut Creek, other communities and industrial users, and in Oakley Water District. CCWD diverts its supply from the Delta and is the single largest CVP M&I project water use.

East Bay Municipal Utility District (EBMUD) has been included as a potentially affected provider, but the district is not included in the analysis because EBMUD is entirely unaffected by the action alternatives. Therefore, to include EBMUD would reduce the apparent significance of impacts to other providers.

SAN JOAQUIN VALLEY CITIES GROUP

San Joaquin Valley Cities are primarily those with some current or planned use of CVP or SWP supplies. The largest single city in the region that obtains CVP supplies is Fresno. Other CVP water contracts involve the cities of Avenal, Coalinga, Huron, and Tracy. Bakersfield is included because of SWP water use through Kern County Water Agency (KCWA). Several cities use local surface water supplies that may be affected by the supplemental water program. Stockton East and Modesto Irrigation District are included in the group.

CENTRAL AND SOUTH COAST GROUP

The South Coast M&I demand exceeds the demands of all other M&I regions combined. The region is potentially affected via the SWP and the California Aqueduct and includes Metropolitan Water District of Southern California (MWD) and all SWP M&I entitlement holders south of Kern County, encompassing Ventura, Los Angeles, and Orange counties and the western portions of San Diego, Riverside, and San Bernardino counties. The group includes the Antelope Valley and Mojave River planning subareas of the South Lahontan region and the Coachella planning subarea of the Colorado River region.

Central Coast SWP contractors are Santa Barbara FCWCD with an SWP entitlement of 42,500 acre-feet and San Luis Obispo County FCWCD with an entitlement of 4,800 acre-feet. These districts are potentially affected via the Coastal Aqueduct of the SWP.

THEORETICAL BASIS OF MODEL

The theoretical basis for the model lies in market theory and the theory of regulated utilities. The model includes demand and supply functions for water. Price, however, is based on the idea that regulated utilities will charge average cost for water supplies. The model also borrows several concepts from past M&I modeling in California, especially the Economic Risk Model (ERM) developed by the California Department of Water Resources (DWR) to estimate costs of shortage and optimal water supply development for California's South Coast Region.

WATER DEMAND AND VALUE

The measurement of shortage costs, water transfer demands and municipal water use are all related through municipal water demand. Economic demand relationships express quantity demanded as a function of price. When shortages are imposed, the analysis uses a water demand function to calculate the cost of shortage to M&I customers. The purchase of M&I water transfers and other alternative supplies considers the willingness of customers to pay for these supplies; customers may prefer more shortage to the high cost of alternative supplies. Finally, M&I providers pass on any changes in the long-run costs of water supply to customers. Because a change in water price also causes customers to change their water use according to the demand function, the analysis estimates water use as a simultaneous solution of supply and demand functions.

The proper estimation of municipal water shortage costs has recently been debated among economists and before the State Water Resources Control Board (SWRCB). Because of this debate and the importance of water demand to the analysis, the following four potential approaches are discussed here:

- use of alternative costs
- use of contingent value studies
- use of the ERM marginal loss function
- use of observed water price and use levels with demand elasticities from secondary sources

The following four sections discuss these approaches and highlight some potential weaknesses. The last approach was chosen for its consistency with economic theory, and because it can be tailored to observed prices and quantities for the entire range of potentially affected providers.

Alternative Costs

The alternative cost approach recognizes that water users faced with shortage have identifiable alternatives. Shortage can be mitigated or eliminated with certain actions and/or devices, and the cost of using these alternatives is used to estimate the cost of shortage. The alternative cost principle is well established, but there have been few applications to water shortage at the end-user level in terms of costs that might be paid by end users to reduce shortage costs.

Lund (1995) applies a hypothetical example in a linear programming context to select a best mix of residential water-saving alternatives. The example uses 12 explicit alternatives involving water-saving devices and reduced water use, and 4 different water supply reliability sequences. Results imply an average value of water used to eliminate shortage ranging from $2,000 to $3,000 per acre-foot per year.

The alternative cost approach is appropriate when it can be established that the costs of alternatives are the actual and total costs paid. In this case, some of the costs of water shortage include aesthetics, information, and transactions costs which are hard to measure. In this analysis, explicit supply alternatives and their costs are included, but not at the end-user level. In the long-run, shortage is eliminated by providers (not end users) by an increase in use of water supplies and increased water price. In the-short run, supplies are purchased by providers only after mandatory drought conservation. More discussion of alternative supplies and their costs is provided below.

Contingent Value Studies

Contingent value studies use surveys to query consumers about the value of goods; in this case, residential water supply. Carson and Mitchell (1987) surveyed California residents about their willingness to vote for a hypothetical initiative which would increase water supply reliability at a given cost. Results suggest median annual willingness to pay (WTP) per household to avoid specified water shortages as shown in Table II-1.

TABLE II-1

RESULTS OF CARSON-MITCHELL CONTINGENT VALUE SURVEY

Shortage	Frequency	Median WTP Per Year	Implied Value per acre-foot (af) per Year (1)
30-35%	1 in 5 years	$114	$3,508
10-15%	1 in 5 years	83	6,640
30-35% and 10-15%	Each in 5 years, 2 in 5 total	258	5,733
10-15%	2 in 5 years	152	6,080

NOTE:
(1) Calculated assuming .5 af per household. $3,508 = (114/.5)/(.2•.325).

Mean WTP per household was about three times the median values, suggesting that average WTP was far larger than the values provided in Table II-1. In any case, the values imply a threshold (residents appear to place a large value on avoiding any shortage) or declining marginal cost of increased shortage. For example, the first two scenarios show that median WTP to reduce shortage by about two-thirds (to 10 to 15 percent) declined by only $31 ($114 to $83), or less than one-third. Alternatively, tripling the shortage from 10 to 15 percent to 30 to 35 percent increases WTP by only $31, so average WTP decreases as the shortage increases. This implies that the average cost of shortage per unit water decreases as shortage increases. This decrease is consistent with a threshold effect as discussed below, but is otherwise counter to standard economic logic. Economic theory suggests that average cost should increase, not decrease, as shortage increases.

Barakat and Chamberlin (1994) used similar contingent value methods to estimate WTP to avoid shortages of varying frequency and magnitude in nine water districts including SCVWD, CCWD, ACWD, and MWD. Dollar results in terms of annual WTP are similar to results from the Carson-Mitchell study, but some of the hypothetical shortages were less frequent. Implied annual values of water used to eliminate shortage are $11,000 to $52,000 per acre-foot (Illingworth, 1995).

The validity and proper interpretation of these results have been discussed among economists. In one view, the data suggest a threshold effect. In this view, once some shortage has been imposed, a relatively small additional cost is associated with avoiding more frequent or larger shortage. In another view, residents did not provide accurate estimates of their WTP. The threshold effect could be explained by a common finding in contingent value studies known as embedding: "the value placed on a resource is virtually independent of the scale of the resource" (McFadden, 1994).

The contingent value studies used in California both relied on the referendum format which allows respondents to vote for or against a hypothetical initiative. Some experimental data suggest that persons who vote "yes" in a hypothetical situation will often change their vote to "no" when faced with the real choice (Blackburn et al., 1994). In another experiment concerning the value of wilderness, the referendum format was compared to an open-ended WTP question (McFadden, 1994). The referendum format gave "far higher estimates of WTP" that were "economically as well as statistically significant." Referendum mean and median WTP values were 10 and 4 times the open-ended WTP values, respectively.

Some studies have found that contingent valuation does not produced biased results (Carson et al., 1986), but results of the Carson-Mitchell and Barakat and Chamberlin studies are not used in this analysis because these particular results are not considered reliable for two reasons 1) the results are inconsistent with economic theory, and 2) other studies have found that the hypothetical referendum format may not provide reliable results. In addition, contingent valuation was developed to estimate values for goods which do not have prices, or prices are not an appropriate indicator of marginal value. Most water use is priced, but some qualifications apply as discussed below.

Economic Risk Model Marginal Value Function

The third approach to residential shortage costs relies on the ERM developed by DWR. The model simulates drought water management activities and shortage costs within MWD's service area. A loss function, which calculates the costs of residential shortage, was developed by DWR by considering results of the Carson-Mitchell contingent valuation study and other information. Table II-2 shows some marginal values derived from the model.

TABLE II-2

ERM MARGINAL VALUES OF WATER FOR RESIDENTIAL USE AS A FUNCTION OF PERCENT SHORTAGE

Percent Shortage	$/af/year Marginal Value	Average Demand Elasticity (1)	5 Percent Arc Elasticity of Demand (2)
0	299		
5	1,022	-0.021	-0.021
10	1,692	-0.021	-0.076
15	2,310	-0.022	-0.137
20	2,875	-0.023	-0.204
25	3,387	-0.024	-0.281

NOTES:

(1) Elasticity over entire range of shortage. The percent shortage is the percent change in quantity, and the percent change in price is the change in marginal value at the given level of shortage divided by the marginal value with no shortage ($299 per af). For example, -0.021 = -0.05/((1022-299)/299).

(2) Elasticity over the previous 5 percent increment of shortage.

The elasticity of demand is the percent change in quantity associated with a percent change in price. Demand is inelastic if a percent change in price results in a smaller percent change in quantity demanded. The ERM loss function can be used to derive an implied elasticity of demand. The ERM loss function suggests a highly inelastic demand of about -0.02 over the entire range of shortage, but demand becomes more elastic with increasing shortage. The elasticity over a small range (the arc elasticity) increases, reaching -0.28 at the range of 20 to 25 percent shortage.

The ERM is not used in this analysis because it covers only the South Coast Region. The loss function is also not used because of its basis in the Carson-Mitchell contingent value study and because it cannot easily be tailored to other M&I regions.

Combine Observed Prices and Quantities with Estimated Demand Elasticities

Economic convention suggests that analysis of economic values should consider price data when prices are available. The approach to M&I water valuation used in this analysis relies on verifiable water price and quantity combinations and secondary studies on elasticity of demand for residential water. Short- and long-run elasticities of demand with 2020 residential price and quantity combinations are used to develop water demand functions and values for various levels of shortage. These demand functions are used to value shortage and, in the long-run analysis, to determine a new price associated with reduced deliveries and increased costs.

Price is an indicator of a good's value because it suggests how much buyers are willing to give up to have the good. Price is an unbiased indicator of value when buyers must pay the price and are free to take the quantity they want at that price, use of the good is rival (ones use precludes anothers use) and use of the good does not result in externalities. These conditions are generally met for residential and municipal water use with three possible exceptions; 1) some water users do not pay the price of water, 2) in mandatory conservation, water users are not free to take the quantity they want, and 3) urban water use has external effects in urban areas. These potential problems are discussed below.

First, some water users do not pay the price being charged for the water they use. Some persons rent homes, businesses, and apartments where their water bills are paid by the landlord. Many other persons use water in roles such as employees, hotel guests, visitors to public facilities, or guests at a club where they do not pay a price for water use. In this case, the demand function is too inelastic for the purpose of estimating value lost during shortage. With inelastic demand, a higher price results in a smaller percent change in quantity used. The demand is in fact inelastic, but it is inelastic because some users pay no price in any case, not because of the relative value of the water. In shortage, the users who pay no price may be required to reduce their water use. The incremental shortage costs of these users are likely to be very small because they previously had no price incentive to conserve. If forced to conserve, they should be able to reduce their use for a relatively low cost. Therefore, use of a statistically estimated demand elasticity in combination with current retail prices is likely to overstate shortage costs to the extent that water bills are paid by someone other than the water user. It is believed that most water use is paid for by the user, so this problem should not be important overall.

Second, during mandatory conservation, water users are not free to take the quantity of water they want. This means that quantities of water use during mandatory conservation should not be used to estimate demand functions.

Third, municipal water is not a "perfect good." Some water use has external effects on other persons. Landscape irrigation results in recharge of groundwater. Private landscaping has some external benefits; shade and aesthetics for example, but some costs as well, such as increased incidence and severity of pollen allergies. Overall, the external values of urban water use in urban areas are probably not large in comparison to the internal, private benefits.

Finally, there is an issue of WTP versus willingness to accept compensation (WTAC). The payment needed to persuade residential users to accept a shortage is not necessarily the same amount they would be willing to pay to eliminate the shortage, and these amounts can also differ from the amount of consumer surplus estimated from a demand function. Differences among the three are partly due to the income effect, which involves the reduction in real income caused by a price change. If there is an income effect, the consumer surplus measure will overstate WTP and understate WTAC. For low-priced goods used in small quantities, the income effect is likely to be zero and this distinction could be ignored. However, water bills in the range of $20 to $50 or more a month might be a significant share of disposable income for some persons. Furthermore, economic convention would suggest that WTAC should be used when the consumer has a good (water) and must give it up because of a policy measure. This argues that a demand more inelastic than estimated in demand studies might be used to avoid understating WTAC.

In summary, none of these factors provide a strong argument against use of economic demand functions to estimate the value of municipal water. Therefore, the price of water should be close to the incremental value of water to end-users. A small percent shortage should not increase this value by a much larger percent unless demand is very inelastic. Many secondary sources referenced below suggest that residential demand is inelastic, but not extremely so, and this inelasticity may partially reflect incomplete price signals. Therefore, the selected approach uses observed prices and quantities and demand elasticity to estimate economic value.

Water prices and quantities can be readily obtained, but appropriate demand elasticities must be estimated. Many studies of the elasticity of demand for residential water supplies have been conducted. The studies typically use real data on water prices and quantities used to estimate residential price response. Some elasticities reported by Gibbons (1986) and DWR (1991a) are provided in Table II-3.

TABLE II-3

ESTIMATES OF THE ELASTICITY OF RESIDENTIAL WATER DEMAND

Author	Location	Elasticity
DWR, 1991a	California	-0.2 to -0.5
Weber, 1989	EBMUD	-0.1 to -0.2
Foster and Beattie, 1979	"Southwest"	-0.36
Billings and Agthe, 1980	Tucson	-0.39 to -0.63
SOURCE: Gibbons, 1986; DWR 1991a.		

In California, CCWD (1989) cites a long-run residential elasticity of -.2 to -.4. with a very small elasticity in winter and -.35 in summer. MWD (1991a) suggests single-family and multiple-family elasticities of -.31 and -.14, respectively, each measured as an average of summer and winter elasticity. The overall, weighted urban annual average price elasticity is estimated to be

-0.22. Weber (1989) provides results from within EBMUD and finds "it is probably safe to conclude that the long-term elasticity under the conditions identified is in the range of -0.1 to -0.2."

A short-run elasticity of demand is less (more inelastic) than the long-run elasticity because people are able to make fewer adjustments in the short run. A change of behavior takes time. In a drought, for example, a price increase will have a limited effect on water use until people know about the price change, decide to do something, and succeed in reducing their water use. There is little information in the literature on short-run demand elasticities. Carver and Boland (1980) surveyed the literature and applied a Nerlovian lag formulation to data from the Washington D.C. area. They find that "the short-run (one year) elasticity for total water use is evidently small" and tentatively suggest a range of -0.1 to -0.2.

These studies all suggest that residential water demand is quite inelastic, but not extremely so. Further, the literature seems to suggest that demand in California is somewhat more inelastic than in other regions. This could be due to higher incomes, lower real prices, or more permanent conservation than in some other regions.

Given the substantial variation in demand elasticity estimates that exists, we feel justified in adopting a range of elasticity estimates. We use two elasticities of residential, government and other (RGO) demand, -0.1 and -0.2, for the short-run (drought condition) analysis, and -0.4 is used for the long-run analysis.

For commerce and industry, one study (MWD, 1991a) found a commercial and industrial demand elasticity of -0.28. Other studies have found that industry is willing to pay high costs to avoid shortage (CUWA, 1991), a result consistent with inelastic demand. There are probably substantial differences between industries and locations in the elasticity of commercial and industrial demand caused by different roles of water in production, costs and availability of substitutes, water costs as a share of all costs, and costs of wastewater management and effluent control. Overall, limited information is available, but it is believed that the demand elasticity for commerce and industry is generally very low. Therefore, for purposes of this analysis, it is assumed that commercial and industrial demands do not respond to price in the long-run analysis. There are two results of this assumption for the long-run analysis. First, the overall elasticity of demand is less than the RGO elasticity. The elasticity of total urban demand in the long-run ranges from -0.2 (-0.4 * 50 percent) in the San Joaquin Valley to -0.3 (-0.4 * 75 percent) in the Central and South Coast, where 50 percent and 75 percent are the RGO shares in each region. It is believed that these total demand elasticities (-0.2 to -0.3 in the long run) are representative of typical overall demand elasticities for the affected providers, although there is certainly variation by provider as well. Second, change in costs paid by commerce and industry is the total change in municipal costs multiplied by the commercial and industrial share of water use. There is no loss of economic surplus caused by demand response to price.

In the dry condition analysis, commercial and industrial demands can be reduced by mandatory conservation up to 5 percent. The economic surplus loss from these shortages is valued using the same elasticities as for the RGO sector – a range of -0.1 to -0.2.

Several qualifications to the selected approach must be stated. First, no empirical studies on residential water demand in California have been used to obtain appropriate provider-specific elasticities. Elasticity information from outside of California may not be representative. Demands in 2020 may be more inelastic because of demand hardening – relatively inexpensive ways of saving water will be exhausted – but demand may be more elastic if new technology provides new alternatives for end users to reduce their water use. Second, some of the recent prices and quantities used to calculate the demand functions might not reflect a perfectly normal condition that could be expected without shortage. Third, many water users actually do not pay the price of water, so the use of the retail price and observed demand elasticity could overstate end user shortage costs. None of these qualifications are believed to be a systematic source of bias in the shortage cost estimates.

A GRAPHIC PRESENTATION OF THE THEORY

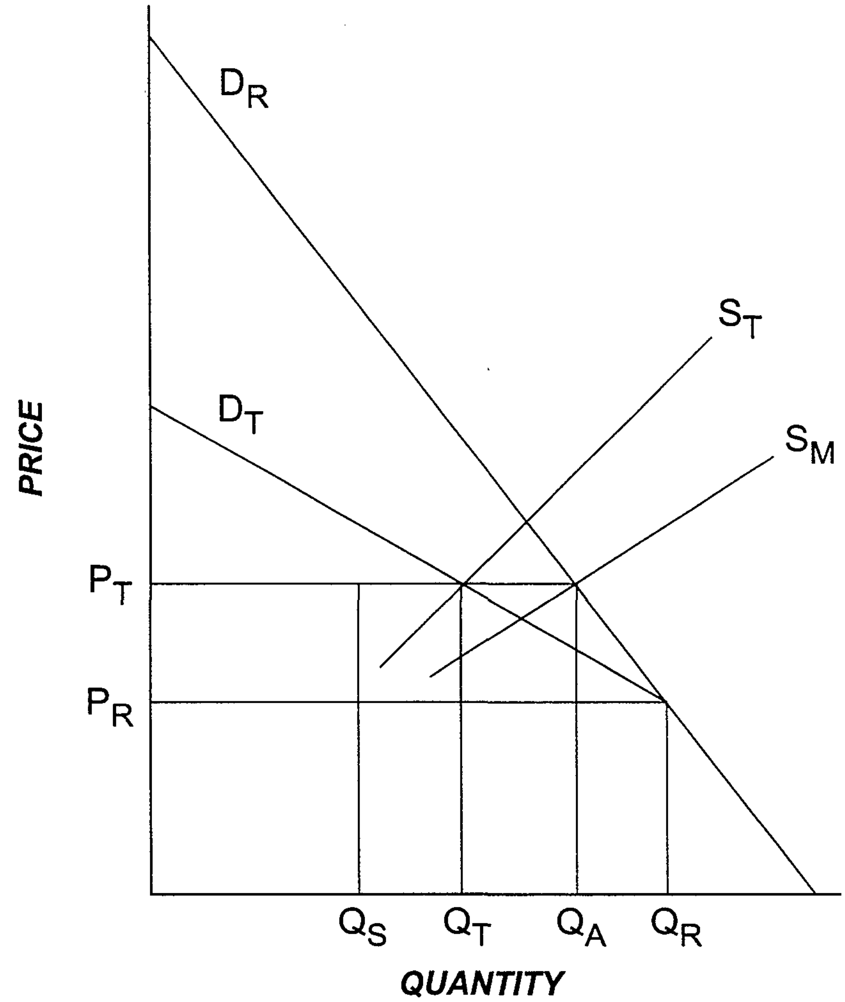
A graphic representation of this theory is provided in Figure II-1. Figure II-1 shows a retail water demand function D_R, a long-run water transfer demand function D_T, and a water transfer supply function S_T. The retail demand function represents the willingness to pay to avoid shortage. The long-run water transfer demand and supply functions are expressed in retail prices; the retail price is the raw water transfer price plus conveyance, distribution, and treatment costs.

Alternative supplies, for purposes here, are any water supplies other than Central Valley transfers that may be used to eliminate shortage. There may be alternative supplies that cost less than transfers or shortage, and the M&I provider would use these less-expensive supplies if they are available. Therefore, the optimum response to shortage may include three strategies: 1) accept some reduction in water use, 2) buy transfers, and 3) acquire alternative supplies.

A water transfer demand function expresses the quantity of transfers a provider would like to buy as a function of their price. The transfer demand function depends on the price and quantity of other supplies that may be available. The quantity of transfers demanded at any price is reduced by the quantity of any other supplies available at a lower price.

Suppose that without shortage, the provider charges P_R and consumers are free to demand quantity Q_R at that price. Provider revenues from water sales are then $Q_R \bullet P_R$. Now allow shortage to reduce the quantity supplied to Q_S. The amount of shortage is Q_R-Q_S. Assume that the total supply of potential make-up water is given by S_M, and the share provided by transfers is given by S_T. The provider should purchase Q_A-Q_S of make-up supplies at a price of P_T. P_T includes all costs needed to deliver the water. The total make-up supplies include Q_T-Q_S of transfers, and Q_A-Q_T is the quantity of other water supplies acquired to reduce the shortage. The water transfer demand function D_T can be derived from S_M, D_R, and S_T, where the intersection of S_M and D_R determine the maximum price that should be paid for any supply, and S_T determines the quantity of transfers bought at that price.

After the purchase of make-up supplies, Q_R-Q_A is the amount of shortage remaining. Consumers would rather accept this amount of shortage than pay any more than price P_T to reduce it. Economic cost of the shortage consists of consumer surplus loss and net revenue losses of providers. In Figure II-1 the consumer surplus loss is $.5 \bullet (P_T - P_R) \bullet (Q_R - Q_A)$. The provider saves variable water costs associated with the original shortage Q_R-Q_S, but it spends more for the raw



D_R = customer water demand function
P_R = the price of customer water with no shortage
Q_R = the quantity of customer water demanded with no shortage
Q_S = the quantity available with shortage
D_T = the demand for water transfers expressed in customer prices
S_M = the supply of all make-up water expressed in customer prices
S_T = the supply of water transfers expressed in customer prices
P_T = the price of water transfers and other make-up supplies purchased to reduce shortage
$Q_T - Q_S$ = the amount of water transfers
$Q_A - Q_T$ = the amount of other supply alternatives
$Q_R - Q_A$ = the amount of remaining water shortage

FIGURE II-1

ECONOMIC THEORY OF THE WATER TRANSFER ANALYSIS, LONG-RUN CASE

water Q_A-Q_S, and the increased cost of these water supply alternatives is a component of shortage cost. The cost of Q_A-Q_S to the provider depends on the market structure for supply alternatives. In a competitive market, the price will be bid up to P_T. If the provider were the owners of the alternatives, or the sole buyer, lower costs might be obtained.

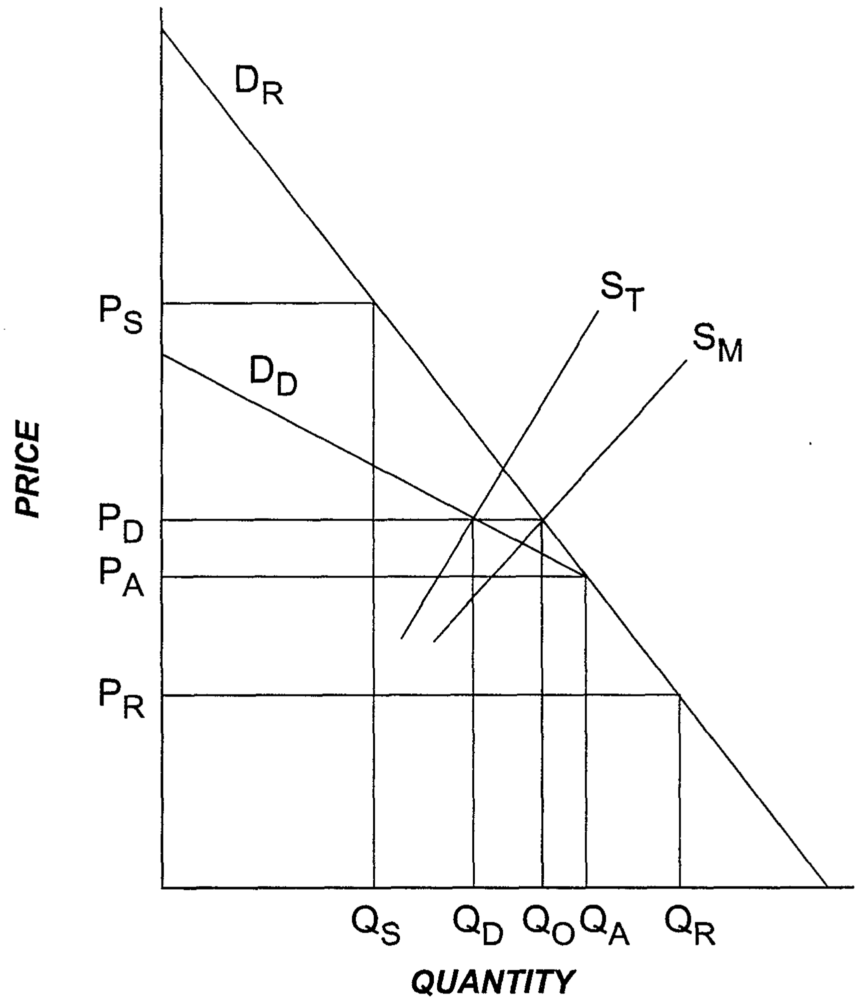
For the purposes of illustration, Figure II-1 is simplified. The actual long-run analysis differs from Figure II-1 in four respects. *First*, all retail demand functions used in the analysis have constant elasticities of demand and are not linear as in Figure II-1. *Second*, the analysis differentiates RGO demands from industrial and commercial demands. In the long-run condition, industrial and commercial demands are not affected by price changes; they are assumed to be perfectly inelastic. *Third*, the analysis requires that provider revenue equals cost in the long-run case, and costs are increased if there is shortage requiring new, higher-cost supplies. In Figure II-1, the long-run case results in a retail price higher than P_R but lower than P_T. A system of simultaneous equations is used to calculate new residential price and quantity given the cost of alternatives and transfers. *Fourth*, there are actually three types of water transfer demand functions used. In each case, the transfer demand functions are linked to the cost of alternative water supplies. This is explained below.

The short-run analysis includes the new transfers and alternative supplies, new retail prices, and the amount of change in demand caused by these new prices from the corresponding long-run case. Therefore, the long-run analysis must always be conducted before the short-run analysis.

The short-run drought analysis differs from the long-run theoretical analysis because we assume a certain amount of drought conservation is required before any supply alternative can be taken. Therefore, the marginal cost of shortage may not be equal to the marginal cost of supplies available to eliminate shortage. We also allow a higher marginal cost for alternative supplies in drought. This cost is reflected in the more inelastic demand for water transfers and, in the Central Valley regions, the higher groundwater cost in the drought condition (Table II-9, page II-25). Also, we assume that the provider does not increase the price of water during drought to cover increased costs or reduced revenues; water providers can temporarily absorb short-run losses with contingency funds.

Figure II-2 illustrates a short-run case in which make-up supply costs exceed the marginal value of shortage. Assume that D_R is now the short-run residential demand function, and quantity supplied falls to Q_S during a drought. The providers' short-run revenues decline from P_RQ_R to P_RQ_S and variable costs of delivery water are reduced. The loss in net revenue (revenue-variable cost) is an economic cost. With the retail price of P_R and the shortage of Q_R-Q_S, there would be an additional cost in the form of consumer surplus loss of $.5(Q_R\text{-}Q_S)\bullet(P_S\text{-}P_R)$. These revenue and consumer surplus losses can be reduced, at a cost, by purchasing transfers or other alternative supplies.

The demand for transfers is increased relative to the long-run case because less of other alternative supplies are available in the short run. There are fewer substitutes available, and S_M in Figure II-2 lies to the left of S_M in Figure II-1. The short-run solution in this case is to purchase Q_D-Q_S of transfers at a higher price (P_D) than in the long-run case. The short-run solution also includes the purchase of Q_O-Q_D of other alternative supplies at a maximum price of P_D.



D_R = customer water demand function
P_R = the price of customer water with no shortage
Q_R = the quantity of customer water demanded with no shortage
Q_S = the quantity available with shortage
D_D = the demand for water transfers expressed in customer prices ($Q_S = 0$)
S_M = the supply of all make-up water expressed in customer prices ($Q_S = 0$)
S_T = the supply of water transfers expressed in customer prices ($Q_S = 0$)
P_D = the price of water transfers and other make-up supplies purchased to reduce shortage
$Q_D - Q_S$ = the amount of water transfers purchased to reduce shortage
$Q_O - Q_D$ = the amount of other supply alternatives
$Q_R - Q_A$ = the amount of mandatory drought conservation
$Q_A - Q_O$ = the amount of voluntary conservation if P_D is charged for make-up water

FIGURE II-2

ECONOMIC THEORY OF THE WATER TRANSFER ANALYSIS, SHORT-RUN CASE

Assume that the maximum drought conservation happens to equal Q_R-Q_A. Marginal WTP to avoid shortage at Q_A is P_A. The optimal solution should include the additional shortage Q_A-Q_O, but shortage above the maximum drought conservation is not allowed in the analysis. With maximum conservation, Q_A-Q_S of transfers and other make-up supplies must be purchased. Total economic loss from the shortage Q_R-Q_S is the sum of the cost of drought conservation programs, the additional cost of make-up water Q_A-Q_S which includes transfers Q_D-Q_S and supply alternatives Q_A-Q_D, the consumer surplus loss $.5\bullet(Q_R-Q_A)\bullet(P_A-P_R)$, plus the net revenue loss from not delivering the amount of shortage remaining which is Q_R-Q_A.

The water transfer analysis is often simplified relative to Figure II-1 or Figure II-2 because the water transfer supply functions, determined by the CVPTM, are often to the right of point (P_R, Q_R). In the long-run analysis, any shortage is then eliminated with water transfers. If the short-run transfer supply function lies to the right of point (P_A,Q_A), any shortage after drought conservation is eliminated with water transfers. That is, drought conservation is required even if transfers are less expensive.

MODEL COMPONENTS AND COMPUTATIONAL PROCESS

This section displays the economic theory behind the M&I analysis in mathematical terms. documents the municipal water transfer demand equations, and shows how some of the other relationships and variables are calculated.

WATER DEMAND FUNCTIONS

The water demand functions are constructed from the RGO demand levels, the observed price of water, and the assumed elasticity. A constant elasticity of demand function is used. The demand functions are of the form:

1) $Q_R = A\bullet P_R^{Ed}$

where:

Q_R = the quantity demanded
A = the constant elasticity of demand coefficient
P_R = the retail price
E_d = the elasticity of demand

The constant elasticity of demand coefficient is calculated from the given elasticity, and quantity and price data as:

2) $A = Q_R/P_R^{Ed}$

Marginal value functions can be derived from the demand functions by obtaining the inverse demand functions, which express price as a function of quantity. Then, quantity is reduced to simulate shortage. Marginal values are generally larger in the coastal areas than in the Central Valley. This follows from the higher price already paid for water in the coastal regions and some higher conservation levels expected by 2020.

CALCULATION OF NEW PRICE IN LONG-RUN CASE

The new price, P_R, needed to cover the change in costs in the long-run case is calculated by solving for P_R from the equation:

3) $P_R \bullet Q_R = [Q_{Ro} \bullet P_{Ro} - (Q_R - Q_S) \bullet (T+D+R) + P_T \bullet (Q_T - Q_S) + P_Z \bullet (Q_A - Q_T)]$

where:

Q_{Ro} = quantity of demand before the shortage
P_{Ro} = the retail price before the shortage
T,D,R = the treatment, distribution and other costs per acre-foot water saved because of the shortage
Q_R-Q_S = shortage before purchase of transfers and other make-up supplies
P_T = the cost/acre-foot of transfers bought, including their T,D, and R
P_Z = the cost/acre-foot of alternative supplies bought, including their T,D, and R

The equation states that new revenue required equals the old revenue minus variable cost savings from the shortage (before purchase of make-up supplies), plus all costs of transfers and other supplies purchased as delivered. P_R is obtained by dividing both sides of Equation 3 by Q_R.

WATER TRANSFER DEMAND FUNCTIONS AND ALTERNATIVE COSTS

M&I water transfer demand functions express WTP for Central Valley transfers as a function of their price. This WTP is related to the RGO retail demand functions. At any given level of shortage, the retail demand functions describe the WTP for water at the retail level. If there were no other alternative supplies and M&I providers were cost minimizers, the retail WTP for water, which is the demand for avoiding shortages, defines the demand for transfers. If the raw water price of transfers plus the costs needed to treat and deliver the water to residences were less than this WTP, then providers could economically sell the transferred water and consumers would want to buy it. In the most general case, the marginal WTP for transfers is the minimum of the marginal WTP for water or the marginal cost of other supplies. The three transfer demands described below are special cases of this general case.

Central Valley Regions

In the two Central Valley regions, the marginal cost of alternative supplies is defined by the cost of pumping groundwater. The fixed cost of pumping groundwater is based on estimates provided by DWR (1994a, p. 150). This perfectly elastic supply leads to a perfectly elastic demand for water transfers, at least within the range of quantity needed to eliminate shortage. If water transfers cost less than the cost of groundwater, transfers are bought. If water transfers cost more than groundwater, the groundwater is used. The analysis can still result in a mix of transfers and groundwater because transfer supply from the CVPTM is upward sloping. Some transfers may be available at a price less than the cost of groundwater, but some are only available at a higher price.

South Coast Region

In the South Coast Region, the water transfer demand function is derived from an explicit alternative cost function. The cost function was estimated using regression based on eight data points from DWR (1994a). The total cost function is,

4) $TC = 158 \cdot Q_Z + .376 \cdot Q_Z^2$

where:

TC = the total cost of alternative supplies
Q_Z = the quantity of alternative supplies bought in thousand acre-feet (taf)

The R-square for the equation exceeded .99. The marginal cost function is then,

5) $MC_Z = 158 + .752 \cdot Q_Z$

where:

MC_Z = the marginal cost of alternative supplies

The water transfer demand function can be derived from this function with a known quantity of shortage S that must be eliminated with alternative supplies and transfers. That is, $S = Q_Z + (Q_T - Q_S)$. Also, at the optimum, $MC_Z = P_T$. By substitution,

6) $P_T = 158 + .752 \cdot (S - (Q_T - Q_S))$

Equation 6) can be used to express quantity of transfers Q_T-Q_S as a function of the price of transfers and the amount of shortage. This equation is used for the South Coast Region. The demand function for the drought condition first accounts for alternative supplies required to meet demand in the long-run case.

In the case of the South Coast Region, specific scenarios concerning the price and amount of water transfer demand were provided by MWD. MWD has stated that "MWD may contract for as much as 50,000 to 100,000 acre-feet of core water. . ." which would be taken annually. In dry periods "the District envisions a need to spot contract for up to 400,000 acre-feet during drought years to meet its goals." The last amount would be increased if the core contracts were not available. More recently, MWD's Integrated Resource Plan has indicated 400,000 acre-feet of water transfer demand during dry conditions which would occur once in four years (MWD, 1995).

The water transfer analysis assumes that average and dry year water transfer demand for the entire South Coast Region is 100,000 and 350,000 acre-feet, respectively. Fifty-thousand acre-feet of the average transfer is available in the dry condition, so total dry-year transfer is actually

400,000 acre-feet. With these constraints and the relationships shown above, the marginal cost of alternative supplies can substantially exceed the price of water transfers.

Coastal Regions Except South Coast

In all coastal regions except the South Coast, being the Bay Area and the Central Coast, the long-run water transfer demand functions are of the form:

7) $Q_T - Q_S = a + b \bullet (P_T - T - D)$

where:

$Q_T - Q_S$ is the quantity of transfers demanded
$b = Ed_t \bullet (Q_R / (P_R - T - D))$
$a = Q_R - (b \bullet (P_R - T - D)) - Q_S$
Ed_t = the elasticity of demand for water transfers

In this equation, Q_S accounts for local and imported supplies, and Q_R accounts for any savings from drought conservation in the short-run case. P_T-T-D is the price offered for transfers at the destination, but before treatment and distribution costs.

The short-run transfer demand functions have the same functional form as 7) except that P_R is replaced with the marginal value of water from the constant elasticity of demand function given the level of drought conservation required. This ensures that the offer price for transfers is not less than the marginal value of water under drought conservation.

To the extent that there are alternative supplies that are less costly than shortage, Ed_t should be more elastic (have a larger absolute value) than the retail demand elasticity Ed. Vaux and Howitt (1983) used an elasticity of transfer demand of -0.4 in an analysis of urban water transfers. Apparently, this elasticity was based on residential water demands. The demand for water transfers in this analysis is more elastic because of the role of supply alternatives. A transfer demand elasticity Ed_t of -0.4 is adopted in the dry condition, when overall demand elasticity, Ed, equals -0.2. In the long-run condition Ed_t is -0.8, when Ed = -0.4.

There are no explicit alternative cost functions for the Bay Area and Central Coast. Rather, the maximum offer price for alternative supplies in these coastal regions is calculated from the water transfer demand functions. The incremental price of alternative supplies, including all costs is,

8) $P_Z = -(a/b) + T + D$

The relationship defined by 7) and 8) can be used because the value of water transfers is the cost avoided by buying them. The analysis without water transfers assumes that the Bay Area and Central Coast pay the maximum offer price for alternative supplies. With transfers, 7) and 8) ensure that these regions buy the least-cost mix of transfers and other supplies, and the maximum offer price for other supplies equals the water transfer price.

The price of alternative supplies before treatment and distribution costs equals the water price at the treatment plant (P_R-T-D) at the current retail price when supply equals demand, but increases as the supply deficit (Q_R-Q_S) increases. By construction, there are no alternative supplies available at a cost less than P_R-T-D. When Q_S is allowed to include the amount of water transfers, the price of alternatives equals the incremental willingness to pay for that quantity of water transfers.

COMPUTATIONAL PROCESS

M&I Economic Analysis

The steps of the M&I economic analysis were displayed in Figure I-1. Long-run average hydrology is input for the long-run case. Without transfers, water supplies are purchased as needed to bring supply and demand into balance given that demand is a function of price and price must be increased to cover the costs of new supplies. The new price and long-run quantity are determined. Drought condition demand is reduced by the demand reduction from the long-run analysis, and the new price and drought condition demand become a point on the short-run demand function. The short-run analysis is then conducted to determine the amount of shortage, drought conservation, and purchase of drought supplies in the short-run drought condition.

Water Transfer Analysis

The water transfer analysis considers how raw water supplies might be reallocated by trading according to relative economic values. Special emphasis is placed on CVP supplies made available for transfer under Section 3405(a). Much of the analysis occurs within the CVPTM. The CVPTM augments the CVPM with municipal water transfer demand equations and other equations that allow but limit movement of water between regions and to M&I providers.

With transfers, the long-run M&I analysis first provides long-run water transfer demand functions to the CVPTM. The M&I transfer demand functions are input for the CVPTM, and the CVPTM also accepts information on the maximum quantity of water demanded and maximum M&I conveyance constraints. The CVPTM then solves for the price and quantity of M&I transfer and returns this information to the M&I economic analysis where the costs of water transfers are analyzed in terms of the M&I impact analysis.

The short-run analysis can be conducted with the addition of the dry condition hydrology. The short-run analysis accounts for permanent transfers bought in the long-run case, and the short-run transfer demand functions are again provided to the CVPTM. The price and quantity of dry condition transfers is returned to the short-run M&I economic analysis.

INPUT DATA AND SOURCES

Potentially Affected Demand (PAD)

The M&I groups and their 2020 potentially affected demand (PAD) appear in Table II-4. The PAD is used for several purposes in the analysis. PAD is obtained primarily from the California Water Plan (DWR, 1994a). The DWR data are specific to regions that frequently do not correspond to affected service areas. In cases where PAD is specific to a provider service area, data from provider planning documents or other provider-specific data were considered. If county land use or provider planning documents indicated a smaller 2020 demand than provided by

DWR, the smaller estimate was adopted. However, DWR's estimates were consistently close to or smaller than other estimates so few adjustments from the DWR data were required. DWR data are also used to split demand between RGO and commercial and industrial demand.

TABLE II-4

M&I PROVIDER GROUPS, 2020 POTENTIALLY AFFECTED DEMAND, AND CVP OR SWP CONTRACT OR ENTITLEMENT

M&I Region	2020 Potentially Affected Demand Served (taf) (1)		References Considered	2020 Potentially Affected Contract (taf) (2)	Source of Water in Contract
	Average Condition	Dry Condition			
Sacramento Valley	933	1,011	DWR 1994 NW and NE regions Sac Valley SCWA 1987 CVP served area & PCWA	663	CVP
Bay Area (3)	1,025	1,142	DWR 1994, SoCWA 1994, DWR 1994a, SCVWD, San Benito Contract SCVWD, ACWD, Zone 7, SF Blackmer 1990, SoCWA 1994	565	SWP, CVP Hetch-Hetchy
San Joaquin Valley Cities	708	717	DWR, 1994, DWR 1994a (Primarily Fresno & Stockton), KCWA 1990, DWR 1994	266	CVP, SWP
Central and South Coast	6,025	6,240	DWR 1994 (Antelope, Mojove, Coachella)	2,592	SWP

NOTES:
(1) These demands include DWR Level 1 conservation.
(2) CVP contracts and water rights and SWP entitlements.
(3) Does not include EBMUD and other portions of the geographic Bay Area.

LEGEND:
taf=thousand acre-feet

Sacramento Valley Group. PAD for this group was obtained primarily from DWR (1994a) and consists of their demand estimate for the northwest, northeast, and the Central Basin East planning subarea of the Sacramento Valley. In the Sacramento region, the Sacramento County Water Agency (SCWA, 1987) also suggests a demand of about 750 thousand acre-feet by 2020.

Bay Area Group. To obtain PAD for the North Bay, data on recent water use were obtained for the cities of Vallejo, Benicia, Fairfield, Vacaville, and Napa, and the American Canyon County Water District (DWR, 1994b). To get to 2020, this use was multiplied by a growth factor of 1.29 as suggested by DWR (1994a).

Several methods were used and compared to estimate a 2020 PAD for the South Bay. First, DWR (1994a) suggests 1,208 and 1,302 thousand acre-feet in average and dry years, respectively. Second, recent water demand projections from the providers in the group were summed. Both methods gave about the same result.

The Bay Area group includes M&I demands served by the San Felipe Unit in DWR's Central Coast Region. Preliminary data provided by SCVWD suggests that south Santa Clara Valley will have 2020 demands of 48,000 and 50,000 acre-feet, and full use of the San Benito M&I contract would be 8,250 acre-feet.

San Joaquin Valley Cities Group. Total 2020 PAD for non-SWP users in the group, based on DWR (1994b) current diversion levels and a growth factor to 2020 of 2.09 (DWR, 1994a), is estimated to be 414 thousand acre-feet. KCWA has an M&I SWP entitlement of 134,900 acre-feet for the Bakersfield area. KCWA (1993) estimated 1992 urban water deliveries of 155 thousand acre-feet. This estimate was adjusted for higher-than-average use that year and increased to 2020 to obtain a PAD of 294 thousand acre-feet.

Central and South Coast Group. Central Coast SWP contractors are Santa Barbara County FCWCD, with an SWP entitlement of 42,500 acre-feet and San Luis Obispo County FCWCD, with an entitlement of 4,800 acre-feet. No unique PAD was identified for this group and entitlement was used as a measure of demand.

DWR (1994a) provided PAD for the South Coast Region. PAD includes the entire South Coast, the Coachella Planning Subarea of the Colorado River Region, and the Antelope Valley and Mojave River Planning Subareas of the South Lahontan Region.

Unaffected Water Supplies

Potentially affected supplies include all CVP and SWP M&I deliveries and other supplies modeled by PROSIM and SANJASM, which include Hetch Hetchy and Mokelumne Aqueduct deliveries, and Stockton East and Modesto Irrigation District M&I deliveries. All of these supplies will reduce shortage and the demand for water transfers, and remaining capacity may be used for transfers.

On the other hand, a large part of the water supplies of some of the M&I groups are directly affected by the CVPIA. Year 2020 unaffected supplies are provided in Table II-5. Many of these supplies are local supplies as defined by DWR (1994a).

The last two columns of Table II-5 show the amount of demand that remains after unaffected supplies are used. This demand is invariant with respect to any Programmatic Environmental Impact Statement (PEIS) alternative.

TABLE II-5

2020 UNAFFECTED M&I WATER SUPPLIES AND SUPPLY DEFICIT AFTER ACCOUNTING FOR THESE SUPPLIES

M&I Group	Unaffected Supplies		Deficit to Replace Before Potentially Affected Supplies	
	Normal	Dry	Normal	Dry
Sacramento Valley	292	368	641	643
Bay Area	319	203	986	1,210
San Joaquin Cities	423	431	286	286
South and Central Coast	2,924	2,798	3,101	3,442

NOTE:
Water supplies in thousand acre-feet per year.
Unaffected supplies are primarily local supplies as defined by DWR (1994a).

Conservation and Demand Hardening

The demand estimates in Table II-4 already account for new and permanent water conservation to 2020. New conservation has other implications for 2020. We assume that, to maintain revenue, 2020 water prices must be increased by the percent decrease in use caused by conservation.

In the future, conservation will continue to be among the first measures used to cope with drought. However, DWR has already included more permanent conservation in its estimates of 2020 demand, and we require even more permanent conservation when retail water prices are increased in the long-run analysis. Therefore, 2020 drought conservation savings are limited because of demand hardening. Most easy and inexpensive conservation measures will already be permanently in place.

Level 1 long-term conservation estimates provided by DWR (1994a) were expressed as a percent of total demand. Table II-6 shows the percent water savings due to DWR's Level 1 conservation by 2020 and additional assumed maximum drought conservation as a percent of 2020 use. The 2020 maximum drought conservation percentages are estimated by assuming that the 20 percent potential under existing conditions will be reduced by the percent level 1 reduction.

Water Prices and Industrial/Commercial Share

Water price data were obtained from a survey of providers. The 1995 prices were increased by the percent water savings from Level 1 conservation expected to 2020 to account for increased average costs per unit water delivered. Table II-7 shows the four M&I groups, representative providers selected for that group, our estimate of 2020 retail average cost of water service, retail water price based on a representative provider, and percent of water use that is industrial and commercial.

TABLE II-6

PERCENT WATER SAVINGS DUE TO PERMANENT CONSERVATION AND ADDITIONAL DROUGHT CONSERVATION ALLOWED IN THE DRY CONDITION ANALYSIS

M&I Group	DWR (1994a) Percent Demand Reduction for Level 1 Conservation		Dry-Year Maximum Percent Conservation if Needed	
	Normal	Dry	RGO	Indus./Com.
Sacramento Valley	8	8	12	5
Bay Area	15	14	6	5
San Joaquin Cities	6	5-6	14-15	5
Central and South Coast	7-9	7-9	13-14	5

TABLE II-7

M&I GROUPS, A REPRESENTATIVE PROVIDER, 2020 WATER COST AND PRICE, AND PERCENT COMMERCIAL AND INDUSTRIAL USE

M&I Group	Representative Provider in DWR (1994a)	2020 Average Retail Cost $/af (1)(a)	2020 Retail Price $/af (2)	1990 Percent Industrial Commercial (b)
Sacramento Valley	Redding, Stockton	275-337	136-222	41
Bay Area	Fairfield, San Jose, San Francisco, CCWD	576-806	401-591	31
San Joaquin Cities	Stockton, Bakersfield	277-328	133-158	45-50
Central and South Coast	Santa Barbara, San Luis Obispo, Los Angeles	505-1,428	418-1,347	24-26

NOTES:
(1) Includes service charges
(2) Not including service charges. Data provided by representative providers. Prices have been increased to account for long-term conservation.

SOURCES:
(a) DWR, 1994b increased to account for long-term conservation from Table II-6.
(b) DWR, 1994a.

The representative provider was selected on the basis of similarity to providers within a group likely to be affected by shortage. For example, the City of Sacramento does not meter so the retail price of water is zero, but Sacramento water supplies are derived from very reliable surface water rights. The Sacramento group includes several providers who receive CVP contract water, are more likely to be affected by shortage, and may be required to meter all service connections. Therefore, we use a positive price for this group from a similar provider, Stockton, a city that currently meters and charges for water.

2020 retail average costs are based on 1991 data for the representative provider (DWR, 1994b). These costs include service charges which are not part of the price of water. The estimation of demand functions requires the price of water, not the average cost of service. Therefore, 1990 water rate structures were obtained from the representative providers and water prices were estimated based on the charge per unit water only. The 1990 prices were often higher than costs a year or two earlier because of drought conservation pricing and the need to maintain revenues with reduced water sales. Small adjustments were made to prices charged by some cities to account for the drought.

Table II-7 also shows the percentage of municipal water used by industrial and commercial customers in 1990 (DWR, 1994a). This percent of water is subtracted from the 2020 municipal demands displayed in Table II-4 to obtain RGO water. Residential water use is typically three-quarters or more of RGO use.

In the analysis, RGO demands are most affected by shortage. In the long run, we assume that industrial and commercial demands do not respond to price. The dry condition analysis assumes that industry and commerce take shortages of no more than 5 percent because industry is typically protected administratively or with alternative supplies.

Drought Year Demand Management and Costs

The recent drought has shown how M&I providers react to extreme shortage. Water transfers during the drought are described in the Water Transfer Opportunities Technical Appendix. But before most transfers occurred in 1991, M&I providers had already initiated voluntary and mandatory conservation to match limited supplies to demand. Table II-8 lists some conservation measures taken in 1990 and 1991.

CUWA (1992) reported conservation measures of 11 member agencies in place as of May 1, 1992. All Bay Area providers were reporting a use reduction goal of 15 percent, except that the San Francisco Water District reported a 25 percent goal. Southern California CUWA members were reporting 10 to 20 percent goals. All of the 11 agencies reported mailed and/or media public information efforts, and all but 2 reported distribution of water-saving devices. Direct economic incentives or surcharges were also used by all but two. Mandatory measures and enforcement were used by only three.

Advertising costs and costs of conservation devices are an important part of drought conservation costs. SCVWD spent $600,000 in 1990 on public information alone (DWR, 1991b), roughly $6 per acre-foot saved. The utilities' true costs of conservation programs are hard to gauge, but we use a figure of $20 per acre-foot saved, which is in addition to the loss of revenue and consumer surplus during shortage.

TABLE II-8

SUMMARY OF DEMAND MANAGEMENT MEASURES IN 1990, AND IN LATER YEARS AS AVAILABLE, FOR SOME PROVIDERS IN THE GROUP

Location	Summer 1990 / later year
Sacramento Valley	Mandatory conservation goal of 20%.
	Mandatory rationing and surcharge on use more than 75% of 1989 use.
Bay Area	Voluntary conservation achieved a 16% reduction / 27% reduction following mandatory conservation in 1991.
	25% system-wide reduction goal with excess use charges / 25% mandatory in 1991.
	System-wide goal of 20 percent reduction; 20% north, 25% south, 19% achieved / In 1991 25% mandatory conservation saved 28.4%.
San Joaquin Cities	City drilled 6 wells. Voluntary conservation.
	Goal to reduce water use by 20%, will increase groundwater if necessary.
Central and South Coast	45% mandatory conservation and increased groundwater use.
	10% voluntary reduction / 15% mandatory in 1991 achieved a 24% reduction.

SOURCES:
DWR 1990, 1991b; CUWA, 1992.

Treatment and Distribution Costs

Treatment, distribution, and other variable costs have been estimated based on information provided in the financial statements of several public water providers (State Controller's Office, 1989) and other information. We use an estimate of $50 per acre-foot for Central Valley providers, $75 per acre-foot for CCWD and the North Bay group, $100 for the coastal branch, and $125 for the other groups. These values are meant to include all variable costs incurred from treatment through delivery. The higher costs are justified by larger service areas and more variation in elevation. Detailed conveyance costs have been calculated for use in the water transfer analysis as explained in that documentation.

Groundwater Costs

Some providers can use groundwater to reduce shortage. Table II-5 displayed unaffected water supplies during normal years and drought. These water supplies often include more groundwater during dry years. For the coastal regions we assume that there is no additional groundwater available to be pumped to mitigate any shortage. The analysis generally allows any shortage in Central Valley M&I beyond drought conservation savings to be eliminated with groundwater, even if more groundwater pumping is required than included in Table II-5, and water transfers into Central Valley M&I regions occur only if the cost of transfers is less than the cost of groundwater.

Table II-9 shows groundwater costs used in the analysis for any urban groundwater pumping caused by the CVPIA. DWR (1994a) provided a range of M&I groundwater costs by region. It is assumed that groundwater costs are in the middle of this range for the normal condition and are three-quarters of the highest cost in the drought condition.

TABLE II-9

URBAN GROUNDWATER PUMPING COSTS

DWR Region	Cost from DWR (1994)	Cost/af Normal Condition	Cost/af Dry Condition
Sacramento River	\$50-\$80	\$65	\$73
San Joaquin River	70-270	170	220
Tulare Lake	80-175	125	150
Source: DWR, 1994a.			

Supply Options

This section discusses supply options and costs in relation to the 2020 baseline condition. New storage, conjunctive use, and reclamation are used to increase average yield, and they may be used to reduce foreseeable drought shortages. DWR (1994a, Table 11-5, Page 288) lists some options and the yields that might be expected during average and drought years.

The unaffected water supplies shown in Table II-5 include some new reclaimed supplies. Some other water supply projects such as Eastside and Los Vaqueros reservoirs are included in both the No-Action and action alternatives. Many other new water supply alternatives are being considered by DWR, in the CVPIA water augmentation study and in other forums. The PEIS No-Action criteria exclude other potential supply options from the 2020 baseline. Nonetheless, we consider long-run supply options generally to see if they offer better options than long-term water shortage or water transfers. Also, the 2020 No-Action condition assumes that water supply equals demand in average years, and more water supplies are needed in some regions to obtain this balance.

In the South Bay Region, several options could yield additional water, but they are interrelated in that they compete for limited aqueduct and groundwater storage capacity. Camp, Dresser and McKee (1994) considered explicit plans to expand groundwater storage using South Bay Aqueduct (SBA) facilities. If excess water is available to store in wet years and recharge capacity is available in existing recharge basins, the cost is small. However, additional costs may be required to expand the SBA or related works to convey water and/or to develop new recharge facilities. Expanded wastewater reclamation will provide some new supplies to the Bay Area before 2020.

DWR (1994a) provided potential yield and cost estimates for the South Delta Water Management Plan (66 thousand acre-feet, \$60/acre-feet) Los Banos Grandes (250-300 thousand acre-feet, \$260/acre-foot), the Kern Water Bank (44 thousand acre-feet average, 430 thousand acre-feet in drought, \$140/acre-foot average) and reclamation of contaminated groundwater (100 thousand acre-feet, \$350 up to \$900/acre-foot). The privately developed Delta Wetlands Project was projected to yield up to 250 thousand acre-feet annually at a cost of $200 to $400 per acre-foot. Some of these options are not now expected to be implemented, but other options have become more viable.

In the South Coast Region, MWD's Colorado River supplies are expected to decline as upstream states make more use of their legal allocations. Therefore, MWD or other south coast providers may work with other Colorado River water users to acquire more reliable supplies. Our 2020 South Coast water balance assumes that (1) South Coast M&I will receive 900 thousand acre-feet on average from Colorado River supplies in the No-Action Alternative, and (2) the Colorado River Aqueduct could operate at close to capacity (1.2 million acre-feet). Therefore, the potential yield of new Colorado River options is 300 thousand acre-feet. A variety of Colorado River water conservation, management, and transfer options could cost about $200 per acre-foot delivered through the Colorado River Aqueduct. The Colorado River options appear very competitive with other options, but the value of Colorado River water is diminished by its high salt content in comparison to some other potential supplies.

Water reclamation costs were estimated using data from the Water Reuse Association of California (1993) and the State Water Conservation Coalition (1991). These surveys obtained capital costs of proposed water recycling facilities throughout the state. Capital costs of reclamation projects currently planned amount to $3,346 per acre-foot for about 600,000 acre-feet of potential yield. The annualized cost with an expected life of 30 years and a 4 percent real interest rate is $194 per acre-foot. The State Water Conservation Coalition (1991) estimates annual capital costs of $249 per acre-foot for projects currently under construction, but costs escalate rapidly for projects in design or planning.

Reclaimed water cannot be supplied for direct potable use at this time. There are few cost-efficient opportunities remaining to exchange reclaimed water for higher quality surface waters. Therefore, additional costs are required to convey the water to landscape or agricultural use, or to groundwater basins for recharge. These options would require additional capital and energy costs, and the delay between recharge and actual use imposes interest costs on the water. There are concerns involving the salt content of reclaimed supplies and effects on groundwater quality, so there may be additional costs associated with water quality management. Recharged water must also be pumped out of the ground and conveyed to users. Camp, Dresser and McKee (1994) estimated annual capital and operations and maintenance (O&M) costs of current and future projects in Zone 7 to range from $880 to $1,590 per acre-foot. This analysis assumes costs of $600 to $1,200 per acre-foot to utilize reclaimed water.

To compare the economics of shortage to the costs of alternative supplies, we must include the costs of delivering the alternative water supplies to the retail consumer. We have considered information on conveyance, treatment, and distribution costs and find that some water supply options are obviously more economical than water shortage costs. Based on economics alone, some No-Action Alternative shortage should be eliminated with some new water supply options before 2020. However, economics alone will not dictate what supply options are built by 2020. Water providers are trying to implement some of these supply alternatives, but they are constrained by complex laws, regulations, and long planning horizons.

Although the No-Action Alternative criteria prevent us from assuming particular projects are completed, the analysis estimates the cost associated with generic options needed to bring long-run supply and demand into balance. DWR (1994a) identifies a 2020 average water shortage in the South Coast Region of 1.4 million acre-feet. The No-Action Alternative hydrology and Bulletin 160-93 demands suggests 1.115 million acre-feet of shortage in the South Coast Region in an average year by 2020. This would be an unacceptable situation for M&I supplies. Therefore, the No-Action long-run scenario allows other water supplies to be acquired until South Coast supplies meet demand. Cost data from DWR (1994a) were used to represent costs of typical new water supplies, and ordinary least squares regression was used to estimate the average cost of new supplies as,

9) $AC = 158 + .376 \bullet Q$

where:

AC is the average cost in $/acre-foot of new raw water supplies
Q is quantity in thousand acre-feet of new supplies

The regression, with eight observations, had an R-square of .99. Standard errors on the intercept and slope were 2.71 and 0.0057, respectively.

Calculation of Direct CVPIA Costs

For purposes here, direct CVPIA costs are CVPIA-mandated water charges and costs of CVPIA-mandated conservation provisions. Section 3407(d) requires that CVP M&I water providers pay an additional $12 per acre-foot toward the restoration fund, indexed upward for inflation from 1992. All 2020 costs are expressed in 1992 dollars, so the restoration fund cost is calculated as the amount of CVP water delivery times $12.

CVP M&I contractors will also pay into the restoration fund from tiered water prices mandated under Section 3405(d). In this analysis, the price paid for the first 80 percent of the contract amount is unaffected by the CVPIA. The next 10 percent of contract water is priced halfway between the contract rate and full cost, and the last 10 percent of the contract quantity is priced at full cost. The full cost rate is calculated using interest costs as specified by the Reclamation Reform Act. The cost of tiered water pricing is estimated based on contract amounts, deliveries, and the three price tiers. The analysis assumes that tiered prices and restoration payments do not affect the quantity of CVP water taken, but total demand is affected because the cost of tiered prices is passed onto final customers in the long-run in the form of higher prices. Table II-10 shows tiered rates used in the analysis. Under the No-Action Alternative, all water is charged at the 1995 cost of service rate.

The CVPIA may require CVP M&I contractors to install meters at every service connection. Table II-11 shows metering costs estimated for some CVP M&I contractors. These costs assume that all new accounts will require meters under California law. Therefore, CVPIA costs are only those required for retrofitting existing service connections.

TABLE II-10

TIERED WATER PRICES FOR CVP M&I CONTRACTORS

M&I Group	$/af Price Charged For		
	First 80 Percent of Contract (1995 Contract Rate)	Next 10 Percent (80% to 90% of Contract)	Last 10 Percent of Contract
Sacramento Valley	$9-43	$10-52	$11-61
Bay Area	27-52	27-61	27-71
San Joaquin Valley	37-65	46-84	55-103

NOTE:
Prices do not include the $12.00 restoration payment. Ranges are for regions within each group.
SOURCE:
Reclamation, 1994b.

TABLE II-11

NUMBER OF UNMETERED ACCOUNTS AND COSTS OF METERING FOR M&I GROUPS

CVP M&I Contractor	Number of Unmetered Accounts (a)	Initial Cost of Meters & Installation (Million $) (1)	Annual O&M Cost of Meters (Million $) (2)	Total Annualized Cost of Metering (Million $) (3)
Sacramento Valley	57,382	22.95	1.15	2.47
Bay Area	0	0.00	0.00	0.00
San Joaquin Valley	82,808	33.12	1.66	3.58

NOTES:
(1) Based on $400 per connection.
(2) 5% of initial cost, or about $20 per meter per year.
(3) Meters depreciated over 30 years at 4% real interest.
SOURCES:
(a) Generally DWR, 1994b, except some data from Conservation Plans.

A review and analysis of CVPIA conservation provisions and plans has been conducted as part of this analysis. Under current conservation guidelines, mandatory best management practice (BMP) A-7 requires that M&I BMPs be implemented if a district delivers 2,000 or more acre-feet of M&I water. Practice A-7 has already been implemented for most water districts that supply M&I water. According to DWR (1994a), "The widespread acceptance of BMP's in California virtually assures that their implementation will become the industry standard for water conservation programs through 2001 and probably beyond." We assume that, absent the CVPIA, nearly all districts providing M&I water would practice these BMPs by 2020. Therefore, there is no significant effect. The review identified no other significant conservation costs to M&I providers.

CHAPTER III

APPLICATION TO THE PEIS

Chapter III

APPLICATION TO THE PEIS

Each PEIS alternative requires two analyses: a long-run and a short-run analysis using average and dry period hydrology, respectively. Each alternative also includes a water transfer supplemental analysis, which also requires long- and short-run analysis. With or without transfers, the long-run analysis is conducted first. Hydrology models provide long-run average water deliveries. Permanent shortage is not allowed as an option for dealing with loss of average water supplies in the long run. Therefore, providers must acquire other supplies to eliminate permanent shortage. Increased purchases of water increase the costs of providing water. Water revenues must equal water costs in the long run. Retail price must be increased, and quantity of demand is reduced. A new lower level of long-run water use is attained, and long-run demand equals supply at the new price. Industrial and commercial demands are assumed to be perfectly inelastic–they do not respond to the price change.

Short-run demand functions, used to estimate costs of shortage during drought, are estimated based on the new price and dry condition demands. Dry condition demands have been reduced for the long-run quantity response to price increases. The short-run analysis requires RGO drought conservation programs before industry or commerce can be shorted or additional drought supplies purchased. Maximum 2020 drought conservation savings incorporate demand hardening between now and 2020. The costs of drought conservation consist of drought conservation program costs, lost revenue reduced for variable cost savings, and RGO surplus losses. Consumer surplus loss is calculated as a linear estimate of the area under the demand function but above the price.

If RGO drought conservation is insufficient to accommodate the shortage, industry and commerce may be shorted up to 5 percent of their demand. A 5 percent industrial/commercial shortage has the same marginal and average cost per acre-foot as a 5 percent residential shortage. If supplies are still less than demand, additional water supplies are acquired. The costs of these supplies are part of the costs of drought, but retail prices are not increased in the short run to cover increased costs.

Results of the M&I water use and cost analysis are displayed in the PEIS and in the Municipal Water Costs Technical Appendix. Results are provided in terms of absolute values and in terms of difference from the No-Action Alternative. Water transfer results are expressed in terms of the difference from the same alternative without transfers, and in Attachment A to the Municipal Water Costs Issues TA, as the difference from the base transfer scenario. The base transfer scenario is the same as the No-Action Alternative, expect that water transfers are allowed subject to feasibility, conveyance losses, and costs.

Several aspects of the application and its results require explanation. First, any provider who has an excess supply in the average condition is assumed to make no use of additional supplies. Therefore, small changes in supply have no economic effect. This occurs only for the South Bay region in the Bay Area, and it occurs largely because DWR Bulletin 160-93 shows excess supply in the 2020 average condition.

The differences in dry condition results between the No-Action Alternative and the action alternatives reflect differences that occurred in the average condition as well as the dry condition, because price, demand, and supplies available in drought are affected by the average condition result. Dry condition costs depend on economics and hydrology in the average condition. Especially, the amount of new supplies bought to eliminate shortage in the average condition carries into the dry condition, except that only 50 percent of average-condition transfers carry into the dry condition. Also, any demand reduction from the average condition carries into the dry condition along with the responsible price.

The increase in dry condition shortage due to an alternative can be calculated as the reduction in shortage, minus the increase in supplies from the average condition, minus the demand reduction from the average condition. Increases in shortage in the average condition lessen the costs of drought in the dry condition because more replacement supplies and less demand are carried into the dry condition.

Restoration payments and metering costs are counted as costs to end users without any compensating benefits. Price changes caused by increased costs from meters and restoration payments affect demand in the average condition, so quantity of water taken is affected by these CVPIA measures. Direct cost increases in the average condition reduce the cost of drought in the dry condition because demand and shortage are less.

CHAPTER IV

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Chapter IV

BIBLIOGRAPHY

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CENTRAL VALLEY PROJECT IMPROVEMENT ACT
PROGRAMMATIC ENVIRONMENTAL IMPACT STATEMENT

DRAFT METHODOLOGY/MODELING TECHNICAL APPENDIX

IMPLAN M/M

September 1997

TABLE OF CONTENTS

C-083954

C-083955

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

CVPIA	Central Valley Project Improvement Act
CVP	Central Valley Project
CVPM	Central Valley Production Model
EDD	Employment Development Department
I-O	input-output
IMPLAN	IMpact analysis for PLANning
NEPA	National Environmental Policy Act
PEIS	Programmatic Environmental Impact Statement
PL	Public Law
REIS	Regional Economic Information System
RPC	regional purchase coefficient
USFS	United States Forest Service

CHAPTER I

INTRODUCTION

Chapter I

INTRODUCTION

Micro "IMpact analysis for PLANning" (IMPLAN) is an input-output (I-O) model used for the regional economic impact analysis. The system consists of regional and national data, data retrieval, model development, and impact analysis software. It is used to analyze regional economic impacts associated with broad-level policy changes or changes in activity in an economic sector.

IMPLAN is a "non-survey" or secondary I-O system, as it does not require primary, survey-based data. It is based on national average technical relationships among industries to which information has been added on regional economic activity. The software allows for national average conditions to be adjusted to account for unique regional conditions. IMPLAN is a popular tool to analyze regional impacts of policy changes because of the ease with which specific regional or local information can be incorporated into a model. While such information generally is from secondary sources, primary data, if available, can be incorporated as easily.

PURPOSE

The Central Valley Project Improvement Act (CVPIA) provides for a wide range of potential changes in Central Valley Project (CVP) operations, and implementation of the CVPIA is likely to have differential effects on various regions in California. Hence, the evaluation of region-specific direct and indirect economic impacts requires the use of analytical tools which can: 1) simulate conditions when direct observations or measures are not available; 2) compare the impacts associated with different alternatives; and 3) identify the differential economic impacts of the CVPIA at the regional level. IMPLAN is an acceptable analytical tool for these purposes.

HISTORY OF THE DEVELOPMENT OF IMPLAN

The history of IMPLAN begins about 45 years after the development of I-O analysis by economist Wassily Leontief (Miller and Blair, 1985). The development of I-O analysis has been well documented and is not repeated here. IMPLAN was originally developed for the U.S. Forest Service (USFS) by the University of Minnesota to assist in land and resource management planning issues. It has been used since 1979, initially as a mainframe-based program. It evolved to an interactive, menu-based microcomputer program in 1989 and has been refined continually since then. Details may be found in Alward, et al., (1989); Minnesota IMPLAN Group, (1994); and MIG Inc., (1996).

OVERVIEW OF DOCUMENTATION ON IMPLAN

MIG Inc. currently maintains and markets the IMPLAN software. It has published a "Technical Analysis Guide" (MIG Inc., 1996) which includes details on the IMPLAN database, construction of I-O accounts, multipliers, and social accounting matrices. The publication also contains an extensive list of citations on IMPLAN and the application of IMPLAN to many resource analysis issues. The most extensive review of the IMPLAN database (Minnesota IMPLAN Group, 1993) provides both a history of development of the database and extensive detail on the several key federal and state sources of data used.

CHAPTER II

DESCRIPTION OF THE METHODOLOGY/MODEL

Chapter II

DESCRIPTION

THEORETICAL BASIS OF IMPLAN

The theoretical basis of IMPLAN consists of two parts: I-O analysis and regional analysis. Each is discussed in this chapter.

INPUT-OUTPUT ANALYSIS

I-O analysis is based on the recognition of interdependence among economic sectors. Each sector not only produces goods and services, but also purchases goods and services for use in the production process. Beginning in the nineteenth century, economists developed so-called general equilibrium models. These models used equations to describe the relationships among sectors of the economy.

Leontief published an I-O system of the United States economy in 1936 (Miller and Blair, 1985). He developed two key simplifying assumptions that allow the empirical estimation of equations associated with general equilibrium models. The first was that a single homogeneous output is generated by each industry, which reduced the many commodities in the model to relatively few. The second was that production equations could be expressed linearly. Additional implicit assumptions of the technique have been identified over time (Young and Gray, 1985).

Transactions Table

The key to Leontief's system is the "transactions table," which portrays the flow of goods and services from producing sectors to consuming sectors. The output of each industry includes sales to all other industries and to ultimate consumers inside and outside of the regional economy, the latter referred to as "final demand." The amount of each good and service used in each industry depends directly upon the level of output for that industry.

Table II-1 presents a hypothetical transactions table. It shows, for each industry, a linear equation depicting the interrelationships among industries by their purchases and sales. The output of each industry is represented as:

$X_i = X_{i1} + X_{i2} + ... + X_{in} + Y_i$, I = 1, n industries, where
X_i is the total output from "selling" industry I,
X_{ij} is the output sold by industry I to industry j, and
Y_i is the output sold by industry I to final demand sectors.

The rows in the transaction table show the output sold by each industry on the left margin to each industry across the top. The columns show the purchases made by each industry across the top from the industries along the left margin. The entry in each cell represents a purchase for the column industry and a sale for the row industry.

TABLE II-I

HYPOTHETICAL TRANSACTION TABLE

Producing Industries	Purchasing Industries			Final Demand	Total Output
	Agriculture	Manufacturing	Services		
Agriculture	$10	$6	$2	$18	$36
Manufacturing	4	4	3	26	37
Services	6	2	1	35	44
Primary Inputs	16	25	38	0	79
Total Outlay	36	37	44	79	196

The first column shows that agriculture purchases $10 of output from itself (i.e., from other agricultural enterprises), $4 from manufacturing, and $6 from services. Agriculture also makes payments of $16 for primary inputs, for a total outlay of $36. The first row shows that agriculture sells $10 of output to itself, $6 to manufacturing, $2 to services, and $18 to final demand. Total output value is $36. For agriculture and all other industries, receipts equal expenditures.

Direct Requirements Table

A direct requirements or technical coefficients table can be derived directly from the transactions table by dividing each industry column element by the column total. The resulting coefficients in each column represent a "production function" for that industry and show the proportion of dollar inputs required to produce a dollar of industry output.

Table II-2 shows that the manufacturing industry requires 16.2 cents worth of input from agriculture ($6/$37), 10.8 cents from manufacturing industries, 5.4 cents from services, and 67.6 cents in labor and other value-added inputs to produce one dollar of output. Hence, 32.4 percent of total manufacturing outlays are purchases from other industries and 67.6 percent are for labor, proprietors' income, and other value-added components.

TABLE II-2

HYPOTHETICAL DIRECT REQUIREMENTS TABLE

Producing Industries	Purchasing Industries		
	Agriculture	Manufacturing	Services
Agriculture	0.278	0.162	0.045
Manufacturing	0.111	0.108	0.068
Services	0.167	0.054	0.023
Primary Inputs	0.444	0.676	0.864

Total Requirements Table

One of the most important applications of I-O is the calculation of output levels in each industry that would be directly and indirectly caused by a change in some component(s) of final demand. The direct requirements table can be used for this calculation in a laborious fashion. Leontief instead developed a much simpler "total requirements" table to summarize the direct plus indirect requirements associated with such a change (Miller and Blair, 1985). The total requirements table, in matrix form, may be derived as:

$X = A X + Y$, where
X is a vector of total industry output,
A is a matrix of technical coefficients, and
Y is a vector of final demands

This equation can be reduced by:

$X - AX = Y$
$(I-A) X = Y$
$X = (I-A)^{-1} Y$

The matrix $(I-A)^{-1}$ is the "Leontief inverse." Table II-3 is the Leontief inverse corresponding to Table II-2. Each cell shows the total outputs (direct plus indirect) required to meet a change in final demand. For example, each $1.00 increase in final demand for agriculture causes a total $1.4459 increase in agricultural output after all rounds of change (direct plus indirect). The $1.00 increase also causes total manufacturing output to increase $0.1996 and services output to increase $0.2582. The total increase in output necessary to meet the $1.00 increase in final demand for agriculture is $1.90.

TABLE II-3

HYPOTHETICAL TOTAL REQUIREMENTS TABLE

Producing Industries	Purchasing Industries		
	Agriculture	Manufacturing	Services
Agriculture	1.4459	0.2678	0.0852
Manufacturing	0.1996	1.1628	0.0901
Services	0.2582	0.1100	1.0431
Total or Output Multiplier	1.9040	1.5406	1.2184

The bottom row of Table II-3 contains the output multipliers, showing the combined direct and indirect output effects caused by a one-unit increase in final demand. Other types of multipliers such as employment and income can be found by using various fixed relationships between output and the other variables. Multipliers are discussed in more detail in a later section of this chapter.

REGIONAL ANALYSIS

Regional analysis is a component of economic analysis that recognizes the distinctness of a region in terms of its resources, industries, and relationships with other regions. In general, smaller regional economies are more dependent on trade with other regions for "imports" and "exports" of goods and services than are larger regions (Miller and Blair, 1985). Regional economic activity is stimulated by the outputs of its export industries (Chase, et al., 1993).

Regional I-O analysis is based directly on the Leontief framework. Regional I-O models are extensions of the basic I-O structure that reflect regional differences in production processes. As an application tool, IMPLAN offers the capability to capture these relationships in straightforward fashion. The matrix algebra is cumbersome, though relatively quick with high-speed microcomputers. The procedure is discussed in MIG (1996).

COMPUTATIONAL PROCESS

The steps in the development and use of an IMPLAN model are relatively straightforward because of the software itself. However, logic and interpretation are required at each stage to minimize the potential for inaccuracies and to maximize the usefulness of the model. The subsequent discussion highlights these steps for IMPLAN-based models in general and for the models developed specifically for this Programmatic Environmental Impact Statement (PEIS). The steps follow those in several sources (Alward et al., 1989).

DEFINE PROBLEM

IMPLAN has been used to analyze such diverse issues as the closure of military bases, entrance of new industries into an area, construction of recreational facilities, and changes in national or local government policies. The specific problem must be defined in terms of the resources, industries, and locations it will affect. In the current study, a reallocation of water supplies and an increase in water costs will affect, among others, the agricultural and recreational sectors throughout the Central Valley and recreational and fishery sectors on the California Coast.

DEFINE STUDY AREA

IMPLAN is a county-based application, and a study area can include any aggregation of one or more counties. The study area defined for a problem is important because the impacts related to the problem depend directly on the size of the area and linkages among the industries. The study area should center around the location of activities for which impacts are to be measured (Alward, et. al., 1989). The area should include the locations of principal buyers and sellers of the goods and services central to the analysis. If household purchases of goods and services are important, the study area should also include the locations of consumers. The area should be sufficiently large to include the industries and consumers which will be affected by the events being analyzed, but not so large as to lose resolution of the most-impacted sectors.

The study area may include the locations of industries having important backward- and forward-linkages with the sectors of interest. Backward linkages are those between an industry and its suppliers, e.g., between vegetable growers and farm chemical dealers. Forward linkages are those between an industry and other industries which use or add value to the product, e.g., between rice growers and rice mills. I-O models estimate economic impacts from backward linkages only. For that reason, any important forward linkages within the study area must be analyzed before the I-O impact analysis and represented in the impact analysis as a change in final demand to the forward-linked industry. Such linkages are discussed below for the IMPLAN models used in the PEIS.

For this analysis, the area potentially affected by the CVPIA was divided into seven geographic regions in California, the boundaries of which follow county lines. The following counties occur within each geographic region.

- Sacramento River Basin: Amador, Butte, Colusa, El Dorado, Glenn, Napa, Nevada, Placer, Sacramento, Shasta, Solano, Sutter, Tehema, Yolo, Yuba
- San Joaquin River Basin: Calaveras, Fresno, Madera, Mariposa, Merced, San Joaquin, Stanislaus, Tuolomne
- Tulare River Basin: Kern, Kings, Tulare
- San Francisco Bay Area: Alameda, Contra Costa, San Francisco, San Mateo, and Santa Clara
- North Coast: Del Norte, Humboldt, Mendocino, Sonoma, Trinity
- Central Coast: Monterey, San Benito, San Luis Obispo, Santa Cruz
- Central and South Coast: Los Angeles, Orange, Riverside, San Diego, San Luis Obispo, Santa Barbara, and Ventura

COMPILE AND EDIT REGIONAL DATA AND I-O ACCOUNTS

The IMPLAN database includes 21 economic and demographic variables for 528 sectors covering every county in the United States. The data are taken from numerous state and federal sources such as the National I-O accounts, the National Income and Product Accounts, Census data, and a host of other published sources. However, many components must be estimated because disaggregated economic data are frequently unavailable at the county level.

Because of the required estimation, the key data for the counties in a region must be reviewed and validated. For this study, the principal IMPLAN database variables analyzed were employment, agricultural output, regional purchase coefficients, and production functions.

Employment

State employment data were found to be the most comprehensive source for the counties included in all regions. California data were obtained from the Employment Development Department (EDD). Because this source does not include the self-employed or sole proprietorships, Regional Economic Information System (REIS) information was used to supplement state data (U.S. Department of Commerce, 1994). Total non-farm proprietors' employment was allocated to various industries by the respective percentages of total non-farm private employment.

The state employment and REIS data were then used to validate the employment and income data in the IMPLAN data base for all the IMPLAN sectors. The REIS proprietorship data were added to the EDD data to estimate total wage and salary plus self-employed jobs, for comparison with IMPLAN data. The 528 sectors were aggregated to various SIC levels to conform to EDD classifications, and the revised data were compared to IMPLAN data. The variance between the two data points for each key sector ranged from 2 percent to 17 percent. Because other comprehensive data alternatives were unavailable, it was concluded that this range of variance was acceptable, and the IMPLAN employment data were not changed.

Agricultural Output

The IMPLAN database contains 23 agricultural industries. The 1991 employment and income data for these sectors are based primarily on data from the 1987 Census of Agriculture. County Agriculture Commissioners' reports were used to evaluate IMPLAN agricultural output data in greater detail. Comparisons were made between the two sets of these values, and changes were made as appropriate.

Regional Purchase Coefficients

A regional purchase coefficient (RPC) is the fraction of a locally produced good or service that is used to meet local demand for that good or service. RPCs must be greater than zero and less than one. The default values in the IMPLAN database are based on a combination of predictive equations and observed values outside IMPLAN.

RPCs in the IMPLAN database were evaluated on the basis of several factors. One was the size of the region, since RPCs are related to trading patterns. A second was the nature of the commodity itself. Within IMPLAN, commodities are defined as bundles of goods. In some cases, e.g. dairy farm products, the bundle of goods is small - primarily raw milk, with some livestock sales. For other commodities, e.g., machine products and bolts, the bundle of goods is large. When such a bundle of goods is large, it is important to know specifically which good(s) are being produced locally, and approximately how much is used to meet local demand. State directories of manufacturers, knowledge of local conditions, and other data sources were used in this evaluation.

Production Function

The coefficients in the direct requirements matrix represent a set of linear industry production functions. After RPCs were modified, production function reports were developed for selected industries. Of particular interest was the food grains industry in the Sacramento River Basin Region, which includes rice and wheat. Most California rice is produced in the Sacramento River Region and rice is one of the key crops potentially affected by the CVPIA. Therefore the production function for food grains in the Sacramento River Region was modified to include only rice, and wheat was shifted to feed grains, which also include corn and barley. The rice production function was estimated using published budgets (University of California, 1989).

DERIVE MULTIPLIERS

A multiplier expresses the ratio between an initial exogenous change and the final effects of that change. Multipliers can express the combined direct and indirect effects or the combined direct, indirect, and induced effects of a change as a multiplier of the direct effect alone. Type I multipliers represent the former and Type III multipliers represent the latter. Type I multipliers are derived by inverting the matrix of a form of the direct coefficient table and include only the effects of inter-industry purchases. Type III multipliers include the effects on household spending induced by the changes being analyzed. As industry outputs change, income payments to workers in those industries change, and these in turn induce changes in consumer spending. These effects work through the economy in a series of rounds, and are summarized by the Type III multipliers.

ANALYZE IMPACTS

Impact analysis involves the measurement of direct, indirect, and induced output, employment, and income effects of changes in final demand in sectors of the regional economy. Impacts are calculated using estimated multipliers and the changes in final demand. The Leontief inverse matrix is used to estimate these effects, as:

$X = (I-A)^{-1}\ Y$, hence
$\Delta X = (I-A)^{-1}\ \Delta Y$, where
ΔY = changes in final demands and
ΔX = resultant changes in total industry outputs

TYPES OF INPUT AND OUTPUT DATA

The IMPLAN database contains a variety of economic and demographic information for the 528 sectors in every county in the United States. Some data are available directly from government services; other data are estimated by IMPLAN staff. By default, if no changes are made to the data for a study area, the user implicitly accepts those values. Far more common is the validation of data as discussed in this chapter.

If it is determined that any part(s) of a regional database should be changed, those changes are incorporated into an import file which is used to modify the IMPLAN data. These modifications include changes in regional supplies, RPCs, industry production functions, and industry aggregation. The file containing the change commands must be created with a text editor separate from IMPLAN.

Impacts are tabulated by IMPLAN in several different types of reports. Four of those most frequently used summarize direct, indirect, induced, and total effects, respectively. Several of each are included in the Attachment to the Regional Economics Technical Appendix for this PEIS. Each report lists, for the sectors impacted by the event, the changes in: total industrial output, employment, employee compensation, proprietors' income, and property income. In addition, the IMPLAN software offers the capability to print many other reports in varying levels of detail (Minnesota IMPLAN Group, 1994).

CHAPTER III

APPLICATION OF IMPLAN TO THE PEIS

Chapter III

APPLICATION OF IMPLAN TO THE PEIS

The general steps involved in applying IMPLAN to this study were discussed in the previous chapter. This chapter includes a discussion of the interaction of the IMPLAN modeling process with other analytical tools employed for the PEIS; limitations of the approach for the PEIS; and representative input and output data for the PEIS alternatives. A complete listing of input and output data for the alternatives is in the Attachment to the Regional Economics Technical Appendix.

INTEGRATION OF IMPLAN WITH OTHER ANALYTICAL TOOLS

The key issue areas from which the regional IMPLAN models draw inputs are agriculture, municipal and industrial water cost, fishing, and recreation. Impacts in each of those areas in turn depend on hydrologic and other impacts which are analyzed earlier in the overall PEIS process.

INPUTS FROM THE PRODUCTION AGRICULTURE SECTOR

Direct agricultural impacts for input into the regional IMPLAN models are based on the Central Valley Production Model (CVPM). CVPM provides acreage, gross revenue, and net revenue for each crop in each region, and each alternative is measured relative to the No-Action Alternative. The 12 crops within CVPM are allocated to 8 crop sectors within IMPLAN on the basis of average acreages from 1987-1990.

Three types of direct impacts are incorporated from CVPM into the IMPLAN models. First are changes in gross revenues associated with changes in crop production, which are input as changes in total value of output of the crops in question. As an example, if wheat acreage declines within the Sacramento Basin Region of CVPM, the decline in gross revenue from wheat is input directly as a change in total final demand for that IMPLAN sector. This is repeated for all impacted crops.

Although CVPM accounts for output price changes for affected crops, the information passed to IMPLAN uses fixed-price estimates of gross revenue. This is consistent with the IMPLAN's structure and data.

The second types of impact measured are changes in farm income associated with changes in net water costs caused by differences in the sources, quantities, and prices of water used by irrigators. These changes include: 1) differences in surface water costs because of higher prices applied to reduced or unchanged supplies; 2) higher groundwater pumping costs because of greater volumes pumped and greater depths to water; and 3) higher irrigation system costs. These costs are taken directly from outputs from the CVPM model runs.

It is assumed that the decline in net farm income caused by higher water costs has two separate effects on farm operations: 1) irrigators will delay or withhold investments in capital machinery and equipment; and 2) less money will be available to farm households for consumer spending. For the PEIS, the income effects are assumed to be split equally between the two types of reductions. Half is assumed to generate regional impacts through the effects on household income and the consequent reduction in household expenditures. The other half is assumed to generate regional impacts by reducing purchases of farm machinery.

Third, forward linkages are considered separately, as explained below, for: rice, fruits, vegetables, and sugar crops in the Sacramento River Region; and fruits, vegetables, and sugar crops in the San Joaquin River Region. Other forward linkages were determined to be insignificant and were not included in the analysis.

The selection of products for which forward linkages are included is based on commodity balance sheets which can be generated with the IMPLAN software package. A commodity balance sheet shows the disposition of the commodity in various sectors within the region and to final demand. If the balance sheet for a particular product shows that a substantial amount of product is processed within the region, then the linkages from the product to the processing sectors are quantified in order to analyze impacts comprehensively. Within the Sacramento River Region, for example, food grains (which include only rice in that particular model) are used in the regional rice milling sector (an intermediate demand for rice), and are exported from the region, both to other domestic and to foreign markets, which represents a final demand. Data in the original IMPLAN database indicated that 28 percent of the rice produced in the region is processed in the local milling sector and that 72 percent is exported from the region. Because the locally-processed percent appeared to be low, it was changed to 90 percent based on conversations with individuals knowledgeable about the rice industry.

Table III-1 summarizes the commodities and regions for which forward linkages are included in the regional models developed for this project. It shows, for each commodity, the IMPLAN database values for the percentage processed within the region ("Processed Proportion") and, for each processing sector, the proportion of total inputs accounted for by the raw product ("Input Coefficient"). It also shows the sectoral dollar impacts that must be accounted for per $1,000,000 change in raw product output.

For example in the Sacramento River Region, 9.7 percent of each $1,000,000 in gross revenue from fruit production is processed by regional canneries and 14.9 percent is processed by regional wineries. The remaining 75.4 percent of gross revenue is accounted for by final demands for fruit, including personal consumption, exports from the region to other part of the state, domestic, and foreign markets, government sales, and inventory change. The 9.7 percent of regional production processed by canneries represents 11 percent of the total value of output in that sector, and the 14.9 percent processed by wineries represents 10 percent of the total inputs used by that sector.

TABLE III-1
SUMMARY OF FORWARD LINKAGE DATA, SACRAMENTO AND SAN JOAQUIN RIVER REGIONS

Crop	Processing			Final Demand Per Million $ of Crop Production	
	Sector	Percent of Crop Processed within the Region	Crop Input Value As Percent of Processed Output	Raw Product	Processed Product
Sacramento River Region					
Rice	Rice Milling	90.0	26.0	$100,000	$3,461,538
Fruits	Canning	9.7	11.0	754,000(1)	881,818
	Wineries	14.9	10.0		1,490,000
Vegetables	Specialties	1.5	0.9		1,666,667
	Canning	7.7	4.5		1,711,111
	Dehydrating	2.7	6.4	881,000(2)	421,875
Sugar Crops	Sugar refining	35.2	9.6	648,000	6,750,000
San Joaquin River Region					
Fruits	Canning	12.6	11.1		1,135,135
	Freezing	4.0	14.0		285,700
	Wineries	8.3	10.7	751,000(3)	775,700
Vegetables	Canning	6.5	4.5		1,444,444
	Dehydrating	2.2	6.4		343,800
	Freezing	2.4	6.4	889,000(4)	375,000
Sugar Crops	Sugar refining	17.9	9.6	821,000	1864,600

NOTES:
(1) Final demand = $1,000,000 * [1 - (0.097 + 0.149)]
(2) Final demand = $1,000,000 * [1 - (0.015 + 0.027 + 0.077)]
(3) Final demand = $1,000,000 * [1 - (0.126 + 0.04 + 0.083)]
(4) Final demand = $1,000,000 * [1 - (0.065 + 0.022 + 0.024)]

Consequently, in order to capture the effects on various sectors of a $1,000,000 change in gross revenue in fruit production, three separate calculations are performed:

1. The gross revenue change accounted for as final demand for fruit:
   $1,000,000 * (1.00 - 0.097 - 0.149) = $754,000.

2. The change in final demand in the regional canning industry:
   $1,000,000 * (0.097/0.11) = $881,818.

3. The change in final demand in the regional winery industry:
   $1,000,000 * (0.149/0.10) = $1,490,000.

Each of the resultant values is input into the regional model to estimate impacts. The total final demand for fruit production is changed by $754,000; that for the canning sector is changed by $881,818; and that for the winery sector is changed by $1,490,000.

Household consumption expenditures consist of payments by households to industries for goods and services that are utilized for personal consumption. Personal consumption expenditures are based on national data that have been distributed to counties based on the number of households and reported income for three income classes within the counties. Vectors of spending are developed for each income class.

Because of data limitations, the IMPLAN database does not differentiate between farm and non-farm household spending patterns within a given region. Purchases for final consumption are shown within IMPLAN as payments made directly to the industries producing the goods and services. Since individuals buy primarily at the retail level, household expenditures are "margined" within IMPLAN to convert these expenditures back to the source sectors. However, only the source sectors located within the region under consideration are included in the estimation of impacts. IMPLAN has 528 sectors, and because some sectors are not represented in some regions, personal consumption expenditures are not included for those sectors in those regions.

For example, tobacco is not grown or processed in the Sacramento River Region. Hence, regional sales to consumers of tobacco are accounted for in the IMPLAN retail sectors for the region, but there are no payments for regional tobacco growing or processing. Similarly, the Sacramento River Region does not have copper, uranium, potash, or phosphate rock mining; flour blending or wet corn milling plants; chewing gum, vegetable oil, seafood processing, or spaghetti production plants; and a variety of other producing, manufacturing, processing, and wholesaling and retailing sectors. Nonetheless, the IMPLAN database for the Sacramento River Region contains household consumption expenditure data for 396 of 528 sectors. The one-digit SIC classification of these sectors is shown in Table III-1 of the Regional Economics Technical Appendix.

INPUTS FROM RECREATION SECTORS

Overall recreation impacts were converted to specific sectoral impacts for input into the IMPLAN models. Direct impacts of the PEIS alternatives were calculated for the key recreation-affected sectors in each region: food stores, service stations, eating and drinking establishments, hotel and lodging places, and miscellaneous retail establishments. Changes in recreation-related expenditures were estimated for the alternatives, relative to the No-Action Alternative, for the Sacramento River, San Joaquin River, Tulare River, North Coast, and Central Coast regions.

Several important assumptions were made in the economic analysis of recreation impacts:

- Changes in recreation use by residents of a region associated with a CVPIA alternative will be compensated by use of an alternative site in the region so that no net change in expenditures by regional residents will occur.

- Changes in use by people residing outside the affected region will not be so compensated, and all changes in non-resident expenditures will accrue as changes in regional recreation expenditures.

- Of expenditures by non-residents using recreational sites in the Sacramento River, 80 percent of such expenditures will be made in the Sacramento River Basin and 20 percent will be made in the non-residents' home region; for the coastal regions, the respective percentages will be 70 and 30.

The direct impacts were input as changes in final demand in the appropriate sectors of the regional IMPLAN models. Specifically, recreation-related expenditures were estimated for five sectors expected to be most directly affected by each alternative. The sectors and their respective proportions of recreation expenditures in the Sacramento River, San Joaquin River, and Tulare Lake Regions are as follows:

- Food stores: 15 percent
- Service stations: 27 percent
- Eating and drinking establishments: 16 percent
- Hotels and lodging places: 26 percent
- Miscellaneous retail establishments: 16 percent.

Because of the lack of available information on changes in fish abundance, sportfishing catch rate, and commercial harvest levels under the alternatives, changes in expenditures and revenues for these activities were based on hypothetical percent increases. These hypothetical increases could not be associated with a particular alternative, and therefore have not been assessed using IMPLAN.

INPUTS FROM MUNICIPAL AND INDUSTRIAL SECTORS

Direct impacts on M&I were measured as changes in the cost of water. For use in the IMPLAN modeling, these changes are represented as changes in disposable income available for other purchases. The changes are distributed among consumer spending sectors as changes in final demand. As discussed previously, spending patterns are assumed to be identical across all non-farm and farm households within a region. Therefore, changes in disposable income are related to total consumption expenditures, and total consumption expenditures are allocated among the source sectors for the represented goods and services.

INPUTS FROM RESTORATION ACTIVITIES

Direct impacts of construction and other expenditures associated with restoration activities are allocated among several representative IMPLAN sectors: New utility structures, water supply systems, and miscellaneous retail, and other business services. Indirect impacts estimated by IMPLAN are not highly sensitive to the selection of sectors so long as a reasonably representative mix is chosen.

LIMITATIONS ON THE USE OF IMPLAN FOR THE PEIS

The use of I-O analysis in general and IMPLAN in particular imposes some limitations on the PEIS analysis. Those imposed by IMPLAN include the database, the definition of the regions, and assumptions on linkages with other regions. The IMPLAN database, even for a single-county region, is very large, incorporating up to 528 sectors and more than 20 variables. It is virtually impossible to check every number for accuracy. For multi-county regions, the problem is even greater, since validation should begin at the county rather than the regional level. This limitation has been mitigated in part in this study by validating the key numbers and coefficients for the IMPLAN sectors of most interest for the PEIS.

Possible limitations of regional definitions are attributable to the delineation of IMPLAN regions along county lines. Other issues analyzed in the PEIS are based on hydrologic and watershed regions that do not follow county lines. As a result, it is possible that some of the impacts of an alternative on a recreational site on the boundary of one county may fall within the next county which may not be included in the IMPLAN model. This error would be small if the relevant impact multipliers of the excluded county are similar to those of the included counties. In addition, it may be difficult to isolate the impacts of an alternative on a particular sector because of the many counties included within an IMPLAN model.

A third possible limitation attributable to IMPLAN concerns linkages among regions. Each of the IMPLAN models is a single-region model. Other than assumptions on imports, exports, and regional purchases, the models do not explicitly recognize inter-regional interdependencies among sectors. It is believed that the regions defined for the IMPLAN models are sufficiently large so that each is relatively self-sufficient as an economic entity. Moreover, regional purchase coefficients were validated for key sectors in the model. As a result, inaccuracies due to inter-regional effects are believed to be negligible for a programmatic analysis.

Other limitations on the use of IMPLAN in the PEIS are attributable to the I-O methodology itself. One of the most important is that of fixed proportions: for any good or service, all inputs are combined in fixed proportions that are invariant with the level of output. Hence, there is no substitution among production inputs and no economies of scale are possible. Second, each production function incorporates fixed, invariant technology. Such an assumption may be questionable in the case of agricultural sectors, where technological change occurs regularly. This concern is offset in part by the slow, gradual technological changes that are typical in agriculture. However, the more restrictive alternatives could cause large declines in irrigated acreages and stimulate changes in production techniques with different mixes of inputs. Third, I-O does not model any price effects that might be important to a region. Finally, I-O assumes that resources that become unemployed or employed due to a change in final demand have no alternative employment.

Finally, some of the data upon which I-O models are based have been revised since the modeling work was conducted. The files used in the development of regional models for the PEIS were from the 1991 IMPLAN database, dated January 1994, and were purchased in the second quarter of 1994. The Minnesota IMPLAN Group revised the 1991 database in August 1994, but the revision was not used because of the modeling progress to date, the work schedule then in place, and because use of the revised data would have necessitated repeating the entire modeling process.

The 1991 IMPLAN database includes information from the 1987 Census of Agriculture. As additional agricultural data are released, they are incorporated into revised IMPLAN data sets. The last year of the intercensal period (in this case from 1987 to 1992) is often subject to substantial change after the next Census of Agriculture is released. Changes could have included substantial variations in cropping patterns and in other variables because of the drought beginning in California in 1987. The last revision was in August 1994, and staff at the Minnesota IMPLAN Group have stated that the revisions were not significant.

INPUT AND OUTPUT DATA FOR THE PEIS ALTERNATIVES

This information is described in the Regional Economics Technical Appendix.

CHAPTER IV

BIBLIOGRAPHY

Chapter IV

BIBLIOGRAPHY

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